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REPORT ON THE UTILIZATION OF THE BY-PRODUCTS OF THE SUGAR INDUSTRY

CHATURVEDI

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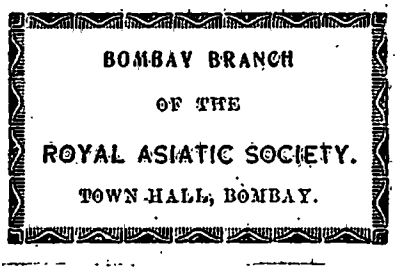

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Bulletin no. 40

REPORT

ON THE

UTILIZATION OF THE BY-PRODUCTS OF THE SUGAR INDUSTRY

By

H. S. CHATURVEDI, B.Sc., Dip.T.I., M.S. (La)

Assistant Research Chemist (Sugar Section), Harcourt Butler Technological Institute, United Provinces, Cawnpore

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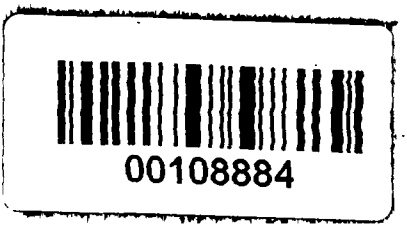

RECTIFYING NOTE

Insert the following *after* the word "purposes" in line 2, on page 98, Bulletin no. 40:

"The author has recently been informed by Messrs. Usines De Melle of Paris that it has now become possible to prepare by Azeotropic processes anhydrous alcohol, which is chemically pure and free of taste for use in the manufacture of very fine chemicals and perfumes. To get this quality of alcohol, it is sufficient to start from rectified alcohol and to use as entraining liquid a Benzine, which is chemically pure, and free of thiophene and all other sulphurous products. It is stated that Benzine of such a quality is easily obtainable in commerce and does not cost more than the usual Benzine."

H. S. CHATURVEDI.

Dated the 26th February, 1937.

2035
1945

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intensive tours throughout the entire sugar belt of Louisiana covering almost every sugar house in that State and getting the first-hand information how every house was carrying on its disposal of the by-products.

After working for a period of 10 weeks with the distillery apparatus manufacturers of America, Lummus and Company, Badger & Sons, and The Acme Coppersmithing and Machine Company, he came over to London and spent some time with the Distiller's Company Ltd., and The Petroleum Storage and Finance Corp., Ltd., as well as at The Hull Distillery Co. Ltd., and The Fuel Research Station in Greenwich.

He then came over to France and spent some time with Messrs. Usine de Melle, and Barbet, and at the beet sugar factory and the absolute alcohol plant of Fabrique Centrale De Sucre at De Meaux. After visiting the two absolute alcohol plants, working by the Melle process near Milan (Italy), the writer returned to India.

Besides getting first-hand information in the above way, the writer had the unique opportunity of meeting and discussing the subject with eminent scientists and industrialists in this field in the various countries, where he spent his time. Among these may be mentioned the following to whom his thanks are due for the compilation of the material for this report:

Dr. Charls E. Coates of The Louisiana State University.

Dr. William L. Owen of The American Biochemical Products Co.

Mr. F. A. Irvine, Technical Superintendent of The Celo-Tex Co.

Mr. T. B. Munroe, Vice-President of the Celotex Co.

Dr. F. M. Hildebrandt, Chief Chemist of the Curtis Bay plant of The U. S. Industrial Alcohol Co.

Dr. Herstein and Mr. A. A. Backus of U. S. Industrial Alcohol Co.

Mr. Board and Mr. Davis of The Distiller's Co. Ltd., and The Petroleum Storage and Finance Co., Ltd., London.

Professor Nash, A. W. of The Birmingham University.

Dr. J. G. King of H. M. Fuel Research Station, Greenwich.

Mr. Gendre of The Usines de Melle, Paris.

Mr. Barbet of The Barbet Company, Paris.

Dr. Charls N. Frey of The Fleischmann Distilling and Malting Corp., New York.

Dr. P. A. Levene of The Rockefeller Institute for Medical Research, New York.

Dr. F. W. Zerban of The New York Sugar Trade Laboratory.

Mr. E. N. Ehrhart of The Suchar Process Corporation, New York.

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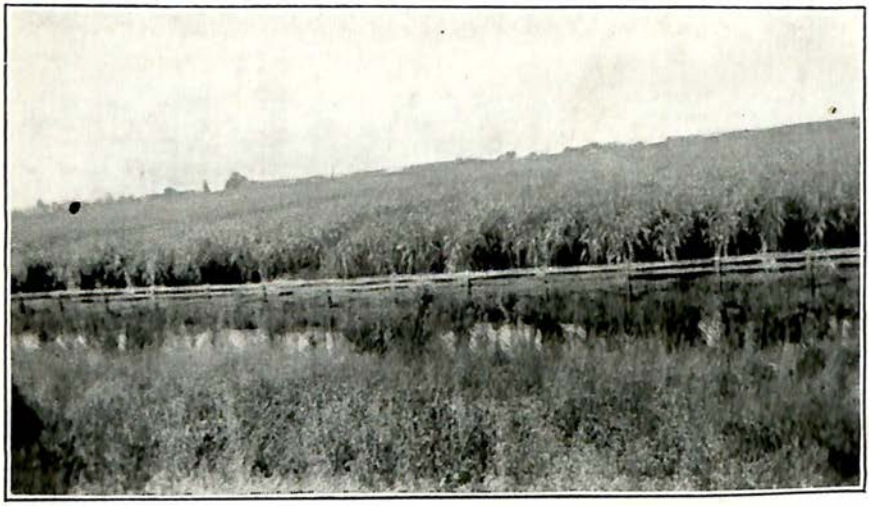


A Sugarcane Plantation in Louisiana

INTRODUCTION

By-products of the sugar industry

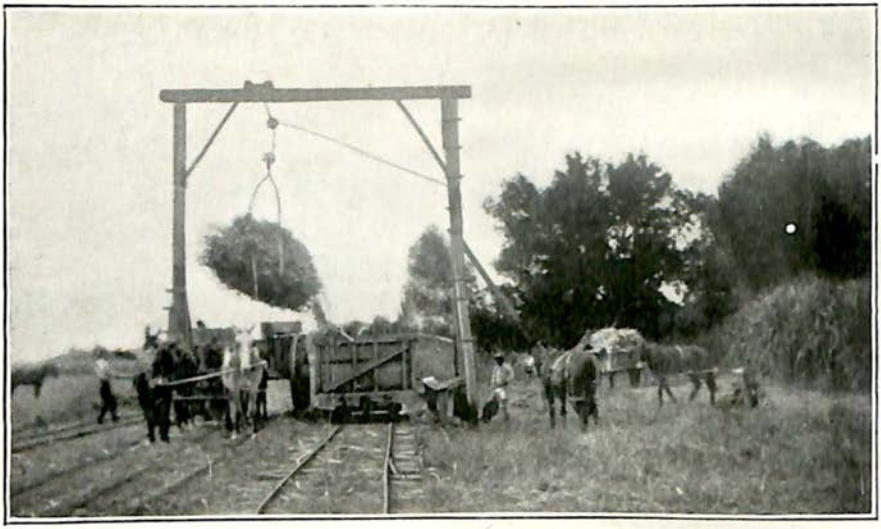
The by-products of an industry may be defined as those substances which have inevitably to be produced in the process of manufacture of the main product. These may, at times, be products of great commercial importance, at others, of normal utility, and at still others, only a waste product of the industry. Depending on its utility, therefore, a by-product may be the stabilizing factor in the existence of an industry, in another it may be returning sufficient profit to help in the maintenance of the industry, while in some it may be a regular drain on the returns from the main product of the industry, requiring expenses for its proper disposal from the factory premises.

The utilization of the by-products determines therefore the success or otherwise of any industry. Many industries owe their very existence to the proper utilization of their by-products, which have in certain cases led to their being treated as the main product, while some others have courted disaster by being unable to do so. The sugar industry is no exception to the rule and requires a very thorough utilization of its various by-products for its proper stabilization in any country. Speaking of sugar industry in a general way, it is divisible into four different sections, agricultural, manufacture, marketing, and by-products.

When the cane gets ripe in the field and is ready for the mill, it has to be harvested. The first by-product which results is called the *cane-trash*, consisting of leaves and a portion of the top of the stalk, which have to be removed from the main stalk before it is sent for milling. On arrival at the factory the cane-stalks have to pass through heavy rollers under great pressure for the maximum expression of the juice from them. The second by-product to be considered therefore is the *Bagasse*, or the main portion of the cane-stalk from which the sugary juice has been expelled out by pressure. The juice subsequently enters the manufacturing process in the factory and produces the main product, viz., cane sugar. The manufacturing processes of the sugar industry may roughly be divided into two. The first is the purification of the juice obtained from the cane, in which lime, carbon-dioxide and sulphurdioxide are the principal

reagents used, and the concentration to a syrup. During this treatment, a large amount of the non-sugar constituents of the juice are eliminated from the main portion of the juice by filtration, decantation,, or a combination of both and are discharged out of the factory under the name of *Press Mud* or Cake. This material therefore is the third by-product of the sugar industry. The second manufacturing process consists of fractional crystallization of the syrup or thick juice to obtain the sugar. In this, vacuum pans and crystallizers are employed to produce crystals, which are separated by means of centrifugals, and finally sold as cane sugar—the main product of the industry. The impurities, organic and inorganic, remaining in the syrup (usually termed non-sugars) prevent the crystallization of a certain part of the sugar, and it is this final mother liquor which is molasses, the fourth by-product of the sugar industry.

Before proceeding with the question of utilization of these by-products of the sugar industry, it is important to know the quantity of each produced per ton of cane and their composition. It should not be forgotten that sugarcane varies in its chemical composition, which depends upon many influences, such as variety cultivated, country where grown, soil, fertilizers used, season and maturity. In Louisiana and ohter southern States of the United States, it varies with the quantity grown upon an acre, the time of harvesting and whether plant or stubble.



Harvested Sugarcane ready for the Mill

CHAPTER I

CANE TRASH

PROFESSOR STUBBS of the Louisiana Sugar Experiment Station found that a ton of purple cane, cut for the mill, contained 844 lb. leaves and 532 lb. tops; while a ton of striped cane had, similarly, 656 lb. leaves and 385 lb. ops. It would be safe to assume therefore that cane-trash represents approximately 33 per cent. of our entire tonnage of cane that is milled every year. Analysis of the tops and trash of cane at Natal showed that in a crop of 30 tons of cane there would be 49 lb. of Nitrogen. 10 lb. P_2O5, and 110 lb. of K_2O, left in the residue of the crop. According to Noel Deerr, the loss of Nitrogen in the leaves and other waste material in the total sugar areas of the world would be about Rs.300,000,000 per annum. It is apparent that we have here a colossal economic waste that should be eliminated, if any practicable means can be found to accomplish it.

An average sample of cane-trash on analysis in Louisiana gave the following figures:

Ether Extract—0·9 per cent. (fats and waxes).

Moisture—3·6 per cent.

Water soluble—6·08 per cent. (sugars, some of the starches, amino-acids, and soluble proteins).

Alkali soluble—51·9 per cent. (Lignins, and hemicelluloses).

Acid fraction—9·2 per cent. (remaining hemicelluloses).

Residual cellulose—25·9 per cent.

UTILIZATION OF CANE-TRASH IN VARIOUS SUGAR-CANE COUNTRIES

There are four methods in general use today for the disposal of cane-trash, which are as follows:

(*a*) Burning it as is done in Hawaii, Java and to a large extent in Louisiana.

(*b*) Allowing it to rot in the fields, where it forms a blanket for the absorption and retention of moisture, as is done in Cuba and Porteuo Rico.

(*c*) Using it as bedding or litter for farm animals and subsequently applying it to the fields as manure.

(*d*) Utilizing it in the preparation of artificial manure.

(*a*) *Burning*—The practice of burning cane-trash in the fields originated and found favour in a number of cane growing countries on account of its being the cheapest and the easiest method for the cultivator to adopt. A consolation was found in its adoption by saying that,

although we lose all the nitrogen contained in the trash, we do utilize for manuring purposes all the Potash and other inorganic constituents contained therein, so that a portion of the inorganic salts removed from the soil by the sugar plant is returned to the soil. A further advantage of this practice was advocated by saying that the phenomenon of burning must necessarily kill a number of insects injurious to the cane-plant in the field, specially the borer and the moths.

While the system of burning the trash in the fields may be the best one from the point of view of its Disposal, hardly anything can be said in its favour from an economic point of utilization of this by-product. Almost everyone engaged in sugar-cane agriculture knows that the pest (Borer) lives in the canes and not on the leaves, and that the moths never stay in the old cane fields, but fly immediately to the young cane rows, where they lay their eggs. Therefore any burning of the cane-trash for this purpose is futile. The only advantage that we, in fact, get by this system of disposal is that the inorganic constituents of the cane-trash are returned to the soil for maintaining its fertility, while the more important organic constituents are being wilfully burnt off.

(*b*) *Allowing it to rot in the field*—In this practice the cane-trash is allowed to rot in the field and after sometime it is ploughed down. Field experiments of this system in comparison to burning were conducted in Hawaii over a period extending to 10 years, and gave successfully better results than the burning system. The advantages which resulted were shown in the improved tilth of the soil, in the ease in which increased yields are obtained, in holding down weeds directly or indirectly, in lessening evaporation during dry weather, and in increasing the ratooning capacity of the cane, all of which make this system of trash conservation one of the most important advances in Hawaii agriculture achieved during recent years. Similar experiments in Brazil have proved that an equal amount of cane can be produced by this system from 450 acres, as from 600 acres of land using the burning system.

In Australia, the value of cane-trash as a surface mulch for ratoons has been clearly demonstrated. A light covering of trash was the means of reducing the soil moisture by surface evaporation to a negligible amount, and the difference between the bare and the covered soil was equal to over an inch of water in favour of the latter. The value of this practice during dry weather will be very evident. The partially rotted trash is then ploughed under, when the final ratoons are cut, thus adding materially to the humus content and fertility of the land. It has been stated that the soil gets five times more humus by conservation of the cane-trash in this way than can be afforded by a heavy green manure crop.

(*c*) *Using it as litter for the farm animals*—With regard to the last system of conserving the cane-trash, i.e., allowing it to remain in the fields and then ploughing it under, experiences have differed materially

both as to methods and results of this practice, particularly as affecting the growth of ratoons. Diversities of soils and of climate appeared to be the controlling factors in the rotting of the trash in the fields. Dr. William L. Owen of the Louisiana Experimental Station carried on extensive experiments to study the phenomenon of cane-trash rotting in the fields under Louisiana conditions. He found out that there is a competition between the growing plant and the soil bacteria for the nitrogen actually present in the soil. The organic matter (cane-trash) offers the bacteria abundant carbohydrate food, the decomposition of which sets free stores of energy for their rapid multiplication, and their immediate need for any available nitrogen for the building up of their cell structure leads to their appropriating it. The equilibrium of the soil nitrogen is thus disturbed and the growing plant suffers in consequence. This state of affairs lasts for some months during which the available soil nitrogen constantly increases, till the equilibrium is restored, but this restoration immediately takes place, when nitrogenous manure is added with the organic matter in the first instance or subsequently. He, therefore, came to the conclusion that it would be more efficient to separate the cane-trash from the soil and compost it with some nitrogenous subtsances, so that the stage of equilibrium could be arrived at without depleting the small quantity of nitrogen in the soil; and when this equilibrium was reached, the compost could be applied to the soil as a valuable manure.

(*d*) *Utilizing it in the preparation of artificial manure*—From what has been said before it might seem that the maintenance of the fertility of the cane fields would depend upon returning to them at least some of the nitrogen contained in the cane-trash. However, the transformation of this nitrogen into a form available for the needs of the crop depends in the last analysis upon whether the ratio of its carbon and nitrogen is sufficiently narrow to ensure the decomposition of the organic matter without drawing upon the available nitrogen already present in the soil. In other words, for every unit of carbon released from its combinations in organic matter undergoing decomposition in the soil, a definite amount of nitrogen is required, so that irrespective of the ratio between carbon and nitrogen in the organic crop residues incorporated in the soil, the decomposition will reach equilibrium at approximately 10 : 1. It is only necessary, therefore, to obtain the information as to C : N ratio of a crop residue to predict, whether its addition to the soil will draw upon the available nitrogen in the latter. Thus for the decomposition of 100 lb. of straw, which contains about 0·5 per cent. nitrogen, 1·5 to 2·0 lb. of added nitrogen are required for its decomposition.

It was precisely this demand of crop residues of wide C : N ratios for additional nitrogen to insure their decomposition, which led the Rothampsted Research Station to develop their ADCO process, which consists in composting such residues with the addition of added Nitrogen

and bases for the neutralization of the acids formed in the decomposition of the organic matter. The principle of their process is perfectly sound, for it is undoubtedly preferable to effect the decomposition of the crop residues under standardized and controlled conditions, where the available nitrogen of the soils will not be drawn upon for its decomposition, and thus for the time being placed beyond the reach of the growing crop. Only the labour required for the collection and composting of such crop residues will make it an unattractive procedure in those countries where labour is very costly. In connexion with the consideration of the ADCO process, it is interesting to note the suggestion of Blewett, that cane-trash near the mills should be composted with filter-press cake and waste sugar-house liquors and be allowed to decompose.

(*e*) *Some other uses*—The possibilities of the utilization of cane-trash, however, are not limited to the preparation of fertilizers or artificial manures, for recent investigations of biochemical processes for the conversion of celluloses into sugar have made considerable progress. The two general methods employed in these processes are as follows :

(1) The initial hydrolysis of the celluloses by acids, and the subsequent fermentation of the sugars by yeasts.

(2) The utilization of micro-organizm capable of both hydrolysing the cellulose and of converting the resulting sugars into alcohols.

The second process would be of much greater value to the industry, since it would eliminate the expense of acid hydrolysis, but so far the species of micro-organisms which can quickly and efficiently perform such services, have not been isolated. Mezzadroli has obtained very promising results from the use of the fungus Mucor Rouxianus for the production of ethyl alcohol from waste supplies of vegetable ivory. The fungus is used merely to hydrolyse the material, the fermentation of the sugar being subsequently effected by yeast. Very promising results have also been obtained in the fermentation of celluloses by micro-organizms, Khouvine, using Bac. celluloses dissolvens has obtained 8·1 per cent. of ethyl alcohol from the celluloses decomposed by this organism. Even better yields of alcohol have been obtained by Fred, Peterson and Viljoen, who employed a thermophilic species for the decomposition of cellulose, and carried out the fermentation at a temperature of 62°C. The products of the fermentation were 56 per cent. acetic acid and 10 per cent. ethyl alcohol. While the difficulties in the way of the development of an efficient bio-chemical process for the conversion of the celluloses in the plant residues are very great, they are by no means insuperable, and their solution will come when the economic pressure will make a concentrated effort in this direction imperative.

Dr. C. E. Coates of the Louisiana State University carried out extensive experiments on the making of Decolourising Carbon from cane-trash. His experiments go to prove that cane-trash could be utilized successfully for the preparation of decolorizing carbons and an excellent

filter-aid at a cost of about $18·00 per ton. This char is as good as Infusorial earth as a filter-aid and has a decolorizing power excelling many commercially popular chars, being able to abstract about 70 per cent. colour against 70—80 per cent. taken out by a high power decolorizing carbon in the American markets.

Recommendations for the utilization of cane-trash in India

Activated Compost from Cane-trash

The four popular methods of utilizing cane-trash, mentioned in the earlier part of this chapter, are after all attempts to return to the soil the fertilizing constituents contained therein in the easiest possible way. The best possible method of conserving cane-trash would, therefore, be one which not only returns all of these to the soil but also some more of the nitrogen from the air by fixation. The writer had been associated with Dr. Gilbert J. Fowler at the H. B. Technological Institute, Cawnpore, in the development of what is now known as the Activated Compost process. In the earlier part of our work the only objection of our critics was about the high cost of collection of the vegetable wastes, e.g., weeds, leaves, etc., to form the raw material for the final compost. In spite of this the process had made a headway in India. The whole refuse of the city of Mysore is now being treated by this process, and Dr. Coleman, the Director of Agriculture, has tried the resulting compost on land irrigated by the Irwin Canal with marked success. In Mysore a contract price of Rs.9 per ton has been fixed. Similar work has been done by the city of Bhopal, where the compost is in large demand at quite a high price. The difficulties attendant on the use of city refuse and nightsoil in India for the making of the Activated Compost will no longer be any hindrance, if the Activated Compost is made with the cane-trash and cow-dung in the neighbourhood of cane-fields, e.g., the lack of modern transport, no water-borne sewage system, heat, the danger of diseases—like dysentery and cholera—if anything goes wrong, and in addition difficulties such as caste prejudice against handling or using human waste materials.

The necessity of organic manure in the soil has been definitely proved by many scientists. It is quite true that to some extent the depleted fertility of the land can be restored by the use of artificial fertilizers, but there is an increasing mass of evidence to show that even crop yields cannot be maintained indefinitely by the use of such fertilizers alone, and that it is essential to maintain the humus content of the soil for proper crop production. Valuable results were thus obtained by Mr. R. L. Sethi, the Economic Botanist to Government, United Provinces, who in field experiments with rice and maize showed that, for equal amounts of nitrogen added, the Activated Compost made at the H. B.

Technological Institute, gave results equal to, or better than, any other nitrogenous manure in common use.

The activated compost made from cane-trash will be containing all the potash and phosphates of the trash besides being a valuable nitrogenous manure for the cane fields.

There is therefore no doubt that the type of organic manure obtained in this way will be of considerable value and an ideal one for cane culture. The cost of production is mainly labour, and as this will only be required for a short time each day, it comes to be a spare-time occupation of the agriculturist, resulting in a very satisfactory return in the way of increased crop yields.

As none of the Indian agriculturists make any use of the valuable nitrogen contained in cattle urine, the writer would suggest that the cane-trash be first used as litter under the animals for one night and then removed for being converted into activated compost.

The following detailed instructions for making activated compost from cane-trash are laid down for the use of those not acquainted with the activated compost process :

1. Collect all cane-trash from the field during the day and make a bedding for the cattle in the evening. On the following morning, take out this material and form a heap about 6 feet long, 3 feet wide, and 2 feet high. The heap may be made longer if the quantity of the material to be treated is larger.

2. Take a basketful or a maund of fresh unmixed cow-dung and make it into a thin mixture with water or preferably with cattle urine.

3. With this solution moisten every portion of the heap thoroughly by sprinkling and stirring. Keep the heap moist from day to day with a thinner solution of cow-dung until the temperature rises and then begins to fall decidedly and the material shows signs of disintegration and crumbles between fingers when handled. The highest rise of temperature goes up to 70°C. sometimes. This fermented material constitutes the starter or activator.

4. At this stage remove a quarter of the heap of the activator (the first heap) and pile it about a foot away from the first heap; this pile is the beginning of the second heap. Make up the first heap to its original size with fresh material. This fresh material should be thoroughly mixed with the rest of the first heap. How this can be best done is a matter of local convenience. Both the first heap and the first quarter of the second heap should be kept moist but not wet by further sprinkling with cow-dung solution.

5. The temperature of the first heap will again rise. As it begins to drop, remove a quarter of the heap again and mix it with the first quarter of the second heap, which now becomes half the size of the

first heap. Fill up the first heap as before with fresh material. Repeat these operations until the second heap equals the size of the first heap. The next operation will be to start a third heap by taking a quarter from the second heap, making up the second heap to its full size with a quarter from the first heap, which is again brought to its full size by a further addition of raw material. The process may be continued until the third heap is equal in size to the first and second heaps. It will be seen that fresh raw material is only added to the first heap.

It may be that by the time the third heap is complete and had been allowed a short period of final fermentation that the material will be ready for use in the fields, as is shown by the complete disintegration into a smooth humus of all the leaves and plant fibres. If this is so, take away a quarter from the third heap and either store it in a heap or use it at once. Fill up the third heap with a quarter from the second heap as before.

If on the other hand the decomposition does not appear complete, begin a fourth heap in the same way taking a quarter from the third heap to start it. It is seldom that more than four heaps will be required. When this stage is reached, it should be possible at intervals of not more than a fortnight to take away a quarter from the last heap for use, fill up the fourth heap from the third, the third from the second, the second from the first, and the first with raw material.

Throughout the fortnight all the heaps should be kept moist by sprinking the cow-dung solution on to the heaps. It will be found that as the heaps become more and more ripe, less solution will be required to keep them moist as the material naturally retains more moisture, so that the first heap will always require the most, and the last heap, the least. No heap must be allowed to become sodden. In course of time it will probably be found that the fermentation becomes more active owing to the development of the organizms specially suited to the local conditions and the raw material undergoing fermentation. It may then be possible to take away half of each heap at a time instead of a quarter.

It will be seen that the total area and volume of the heaps required will depend on the quantity of the cane-trash to be dealt with. The time required to prepare the first heap or activator will depend on the raw material and the weather conditions. It may take a week or a fortnight.

The Agricultural Departments in India are fully alive to the necessity of instructing the cultivator in the better preservation of manure and the use of composts, but there is great scope for an extension of their activities in this respect. It appears to be assumed in some quarters that it is useless to expect the Indian agriculturist to use cow-dung otherwise than as fuel. Experiences at Gurgaon have shown

that this, like many other pessimistic assertions concerning this country, is by no means necessarily true, and that a little intelligent education and strenuous but sympathetic work in the villages can remove this great barrier to progress in Indian sugarcane agriculture.

Demonstration and propaganda work on the above lines should be immediately carried out at the different agricultural farms throughout India, and the cultivator should be convinced and encouraged in the conservation of cane-trash resulting in better crop yields.

The Agricultural Department in Bengal has proved that cane-trash like other vegetable waste materials is capable of breaking down into excellent material approximating more or less closely in appearance and in composition to that of cow-dung.

The writer believes that the Activated Compost process is a very practical method for the conservation of cane-trash under Indian conditions, which can be used with profit by the ordinary cultivator on his own land without incurring any expenses for his manure. Every effort should therefore be made by the departments concerned in order to introduce and make it popular among the ryots.

CHAPTER II

PRESS-MUD

UNDER good working conditions, the amount of cake produced is between 1·25 to 1·75 per cent. on the weight of cane milled. It contains from 60 to 70 per cent. moisture when well pressed. Its composition on the dry basis is between the following limits: Fibre—30 to 40 per cent., soil—10 to 15 per cent., cane wax—20 to 30 per cent., albuminoids—10 to 15 per cent., and calcium phosphate—10 to 15 per cent.

Thus for a sugar factory grinding 500 tons of cane per day, there would be about 7½ tons of press cake to be disposed of every day.

UTILIZATION OF PRESS-MUD IN THE DIFFERENT SUGAR-PRODUCING COUNTRIES

From an extensive tour throughout the sugar belt of Louisiana, the writer found press-cake being used in three different ways depending on the facilities available in the different factories: (*a*) as manure, (*b*) as a road filler, (*c*) for burning with bagasse.

(*a*) *As manure*—Press-cake is almost exclusively used for manurial purposes especially on the stubble canes on account of its phosphatic constituents. In most of the factories the cake as it comes out from the press is directly transported to the fields and applied to stubble canes, in others it is stored on the factory premises in a ditch and transported later when dry.

In the Reserve Central, La., the muds coming out from the presses are mixed with water to form a slurry in a special mixer and pumped by a slurry pump through pipe-lines running all over the plantation. The stubble canes are thus irrigated irrespective of weather conditions. This method of utilizing the press-mud has been found to be more efficient, as the ingredients of the mud get more thoroughly incorporated with the soil particles.

(*b*) *Road Filler*—Some of the factories not having good transport facilities prefer to use the mud as a road filler, in place of earth, in their own premises. This may only be called a method of easy disposal but no utilization.

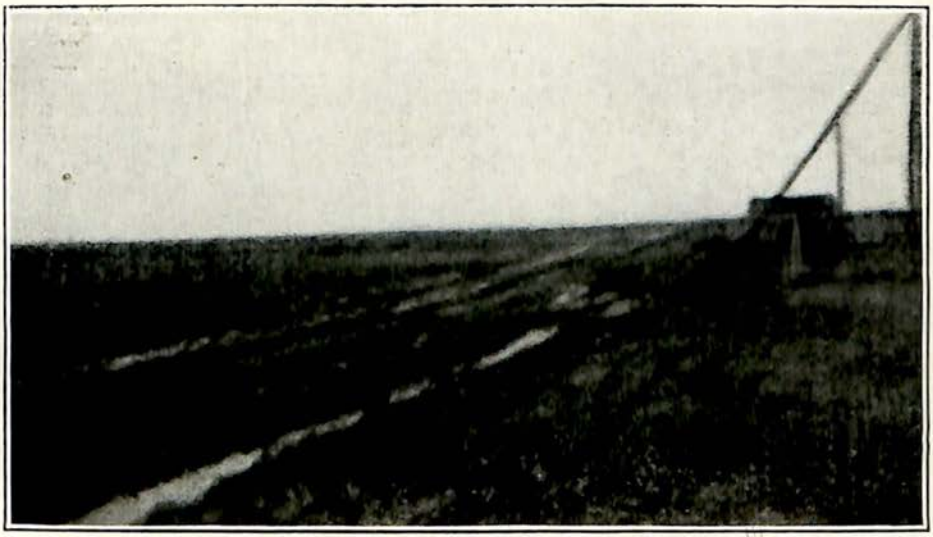
(*c*) *Burning*—The press-mud contains from 30 to 40 per cent. fibre, which is utilized by some of the factories as fuel in conjunction with bagasse. The *ashes* are subsequently returned to the fields as manure.

Recommendations for the utilization of press-mud under Indian conditions

The whole value of press-mud as a fertilizer can be attributed to its phosphate content. It is not definitely proved, however, that the entire phosphate content is in an easily available form for the growth of the plants. Besides, it contains a sufficiently large amount of basic constituents which could, of course, be utilized with advantage on acid soils, but may be detrimental to plant growth on neutral or slightly alkaline soils. The third constituent that may be useful to some extent on rotting is the fibre content which provides the humus. The subject of economic utilization of the press-mud has not been very thoroughly investigated by the scientists; besides, the climate and soil variations in the different tracts are at times so dissimilar that no general procedure for its utilization can be laid down.

The subject therefore requires more investigation before anything can be said in favour or in condemnation of any system to be adopted. If the only fertilizing constituents available are inorganic, it may be worthwhile to utilize the organic part by burning in the boilers in conjunction with bagasse and return the ashes to the field as manure; or, as suggested by Blewett, it should be composted with cane-trash and other sugar-house waste liquors and subsequently utilized as manure after decomposition.

It will be worthwhile to carry out field experiments in the different sugar canegrowing tracts by the experimental farms, and find out the best method of its conservation in their areas.



Cane fields being irrigated with Press-mud Slurry at the Reserve Central, Louisiana

CHAPTER III

BAGASSE

THE amount of bagasse as it comes from the last mill is about 35 per cent. of the weight of cane ground per day. This consists approximately 50 per cent. moisture and varying percentages of sugar. Bagasse is essentially a cellulose material, but like all cellulose materials produced by nature it is in an impure state. Bagasse can be divided into two distinct parts, each with different physical properties, i.e., the Pith (parenchyma) and the Fibre. This makes the utilization of bagasse more difficult than the ordinary fibrous plants. Bagasse contains, in addition to cellulose, lignins, waxes, pentosans, pectin, and a small amount of silica. The percentage of these ingredients will vary in bagasse from different localities. The following table gives the composition of bagasse as a whole, bagasse fibre, and the pith :

TABLE I

	Bagasse entire	Bagasse fibre	Bagasse pith
	Per cent.	Per cent.	Per cent.
Ash	2·40	1·30	3·02
Silica	2·00	0·46	2·42
Fat and waxes	3·45	2·25	3·55
Lignin	19·95	19·15	22·30
Pentosans	24·50	26·11	29·30
Cellulose	46·00	56·60	55·40

It is evident from the above table that the chemical composition of the pith and the fibre are not at such wide variance. It also shows that the cellulose content of bagasse fibre compares very favourably with that of other wood fibres like Douglas Fir, Spruce, Poplar, White Pine and Birch. The only difference being the higher ash content of bagasse in comparison with the wood fibres. The maximum and minimum length of bagasse fibres is between 4 m.m. and 2 m.m. It has therefore a medium fibre length. The fibre of bagasse, like cotton and wood fibres, has a special structure. The density of bagasse pith is approximately 0·20, whereas the density of cork is 0·22 to 0·26. It is cellular in structure and has practically no tensile strength.

If the bagasse coming out from the last mill is passed over a screen, it separates into two portions—the screenings and the residual bagasse. The analyses of these are given separately in the following table :

TABLE II

	Moisture	Ash	Fat	Fibre	Protein	Nitrogen free extract
Whole bagasse	4·53	2·39	0·38	49·66	1·06	41·96
Residual bagasse ..	4·31	3·82	0·50	47·32	1·31	42·74
Bagasse screenings ..	4·78	6·95	0·65	43·91	1·75	41·96
Feeds which contain approximately the same percentage of Nitrogen free extract as the bagasse sample are the following :						
Soybean straw	8·7	7·4	2·5	34·6	5·7	41·1
Oat Hay	11·0	6·8	2·8	29·6	7·9	41·9
Dried Brewer's grain ..	6·8	3·6	7·0	14·3	26·9	41·4
The following samples have approximately the same amount of fat as the bagasse sample :						
Oat Hulls	7·2	7·2	0·6	34·5	2·6	48·0
Corn fodder (stalks) ..	79·0	1·2	0·5	5·6	1·7	12·0

NOTE—The above table has been taken from a letter from Mr. J. A. McClure, Senior Chemist, Food Research Division, Washington D. C. to Mr. Walter Godchaux, Reserve, La., dated the 11th July, 1933. It shows clearly that the bagasse screenings are as good for making balanced feed for the cattle as any other fodder mentioned in the table.

The calorific value of bagasse, perfectly free from moisture, has been found to be between 8,300 to 8,400 B. T. U. In considering the actual fuel value of bagasse as it is burnt on the grates, it must be taken into account that a certain number of heat units are absorbed in evaporating its moisture and heating the resultant vapour to the temperature of the chimney. Further a part of the fuel is consumed in heating the excess air which is drawn through the grates, as well as in heating the products of combustion, this heat loss being dependent upon the temperature of the flue gases passing up the stack. It may be said for comparative purposes that one ton of bagasse, having 40 per cent. moisture and using 100 per cent. excess air, closely approximates the fuel value of one barrel (335 lb.) of crude oil, of one-quarter ton of coal, using the same firing conditions.

UTILIZATION OF BAGASSE

Various attempts made for the utilization of bagasse—Like most industrial waste products, bagasse has had its share of investigation in recent years. With a few exceptions, however, the majority of investigations have hardly gone beyond the laboratory stage. In certain instances commercial ventures were started but failed for one

reason or another. The first successful attempt to utilize bagasse commercially was in the manufacture of fibre-board by the Cole-tex Company of America in 1922. There was enough money and thought spent prior to that date but due to improper considerations of the economies of the processes, they were as a whole doomed to failure at the outset.

(1) *As a fuel*—The use of bagasse as a fuel preceded all other attempts to utilize it. In the earlier days of the modern sugar industry, the milling of cane was so inefficient that it was necessary to dry the bagasse before it could be burnt. As a result, the first published work dealt with the drying of bagasse before burning in the furnaces. The patents of Merrick, Crossley, and Clement, all issued before 1850, were attempts to solve this problem. These were quickly followed by various other patents for "driers" of bagasse. In 1911 Kerr published the most important work in this field. It fully covers the subject and is technically accurate. In more recent years numerous patents have been issued for bagasse drying devices. The necessity for drying bagasse before burning was eliminated with improvements in milling and in the design of furnaces. It next remained to be decided whether it was economical to dry the bagasse before it enters the furnace or to dry it in the furnace itself. The evidence shows that it is advisable economically to dry and burn the bagasse in one operation in the furnace.

The first patent involving the design of a bagasse furnace was that of Marie. This was followed by the patents of Cotiart, Reddie, Sutcliff and Cook. The design of bagasse furnaces received considerably more attention after this and numerous patents were subsequently issued involving more and more complicated designs. The step grate, travelling chain grate, hollow grate bar, and various other types were manufactured. The present tendency is in the direction of simplicity of design. The hearth furnace in combination with suspended flat arches is coming to the front. This is because this type of furnace combines low initial cost, small upkeep, ruggedness and easiness of air control. The handling and stocking of bagasse became mechanical operations.

Bagasse in conjunction with other fuels such as molasses, cane-trash and oil, has been tried. The burning of bagasse in the same furnace with other fuels is not an efficient operation, and is consequently not adhered to on economic grounds.

The production of generator gas from bagasse has been tried, and a commercial plant was built in Brazil producing bagasse coke. It could not succeed commercially as the venture was not economically sound.

Various investigators have biquetted bagasse with the use of numerous binders including the natural binder in the bagasse itself. A notable example is the use of bagasse as binder in the formation of coal briquettes from coal dust. Baling of bagasse in order to store as surplus fuel has also been done.

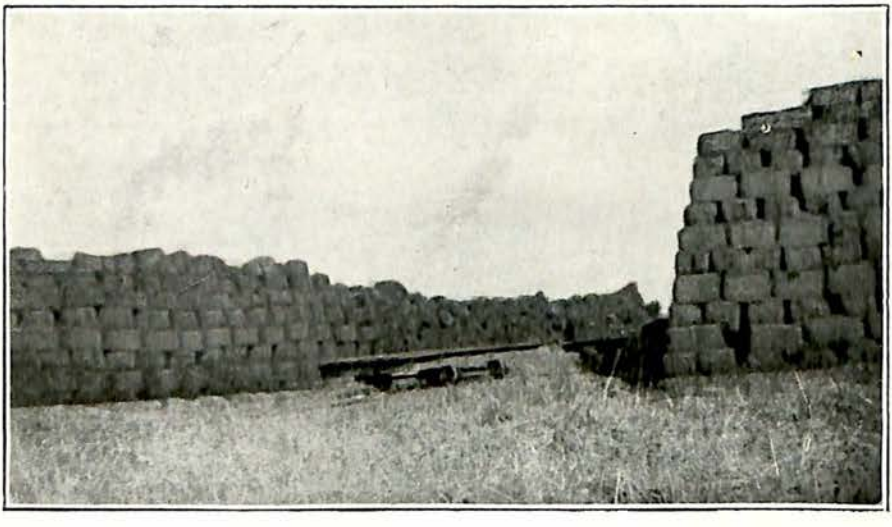
It may be said without any reservation that the most popular use of bagasse in all the sugarcane growing countries of the world, even to the present day, is for fuel purposes to supply the power requirements of the sugar factory itself. The amount of bagasse produced per ton of cane is a variable factor depending on the fibre content of the cane in the different localities. On account of this fact, and also depending on the efficiency of the furnace in use, the quantity of bagasse produced as a by-product in a sugar house, is sometimes sufficient for the entire fuel requirements of the factory, and at others it has to be supplemented by some other fuel. In the more modern plants, which have utilized electric power, there is, however, an actual surplus of the same. The value thus obtained for bagasse varies with the prices of available fuels in the different localities.

(2) *Manufacture of fibre-board from bagasse*—Soon after the signing of the Armistice in 1919, there came a vision of a new and great industry to a small group of young Americans, highly experienced in the various phases of the thermal insulation industry, as it then existed. They decided to build up a big industry for the manufacture of insulation Board. The first requirement for this industry was to obtain a fibre, which would be annually available in vast quantities, and be sufficiently low priced. A number of fibres from American agricultural wastes were examined, considered economically, and finally given up. A number of these fibres showed promise from the purely technical point of view, producing this or that desired property of the finished board. Their economic status was, however, not so good, since many of these fibres had some food value, many were already being used in other industries, and were dependent on the agricultural operations of many farmers. It was also evident that some of these crops were transient, and that all involved a collection problem requiring the organization of many small communities. The technical and economic advantages of bagasse were thoroughly investigated in this connection as follows:

Technical advantages—Purity of the fibre, resistance to decay, length, strength, flexibility and bulk.

Technical disadvantages—Refractive character of the fibre, difficulty to produce cellulose pulps at economic chemical costs or yields, high moisture content of the fibre, problem of handling or storing and preserving it in uniform conditions.

Economic advantages—The cost of growing, harvesting, removing leaves and other non-fibrous tissues, milling, and washing are borne by the sugar industry, large tonnages are concentrated at mills provided with rail or water outlets, the fibres must be used up, its maximum value is that of low grade fuel, it does not belong to any transient industry, all business dealing in securing the fibre is with industrial rather than agricultural agents, there is cheap local labour.



Earlier attempts of the Celo-tex Company to handle and store bagasse at the Sugar Centrals in Louisiana

Economic disadvantages—Location of sugar mills in hot climates and somewhat removed from industrial centres, necessity of replacing fuel by coal, gas or oil, necessity of taking the fibre away from the mill without delay of shut down, bulky character of bagasse resulting in high transportation costs to factory, labour scarcity at time of grinding.

After a very detailed consideration of the above points, the search for the fibre ended in selecting sugarcane bagasse as the raw material for the manufacture of insulation board. The Celo-Tex Co. thus came into being and started operations in the season of 1920 at Marrero, Louisiana. The factory has since developed tremendously and has handled as much as 300,000 tons of bagasse from the different sugar mills in one year. In addition to producing building board, the Celo-Tex Co. also produces various types of insulation boards, carpet lining, linoleum base and "Acousti" Celotex.

In 1926 the production of "T" board in Australia was begun. This board is a mixture of the bagasse fibres and the Ti tree bark. The process is similar in many respects to the Celo-Tex process. A hard dense board is produced.

It was at about this time that the Vazcane process was patented. It consists briefly in separation of the fibres of the cane by grinding and abrasion into very small particles, this being accomplished by the use a medium grit carburundum roll, water being in contact with the cane during the grinding process, the separation of the sucrose from the fibre by the use of an open and efficient diffusion system, the formation of fibre into dense board by the use of board machines, and the recovery of the sugar in the ordinary way. This process has its main advantage in the combination of the two processes in one plant—the production of sugar and the making of the building board in one operation. The fibre board machinery is combined with the sugar making equipment. The great advantage of the process is that the sugar mill operator, instead of the independent board manufacturer, receives the profit from the bagasse board (usually more than the profit from sugar). The value of the board produced is approximately $120 per acre of cane, while the value of sugar produced from one acre is only about $90. The main objection to the process is that it would necessitate the discarding of most of the present sugar machinery and the installation of new one in its place. The marketing problem must also be considered, as no sugar mill can afford the expense of a very large marketing organization. The process as a whole is original and economically sound. Of all the existing processes for the manufacturer of bagasse board, it is the most promising.

In the above process the fibre and the pith are treated together. In William's patent the fibre is separated from the pith and digested with the usual alkalies. The pith is cooked with water to effect hydration. The pith and fibre are then united to form the board. This process

has an advantage because the pith and the fibres require altogether different treatment in order to obtain the maximum strength in the final product, although this advantage is more than offset by the cost of separation.

In two of the three boards described above it will be noted that bagasse is used in conjunction with other fibres. These are used to increase the strength of the board. In the Vazcane process the mass is so finely divided that with the application of pressure the board that is formed is denser and stronger than the usual board.

(3) *Carbon from bagasse*—As early as 1884 Thompson patented an apparatus for the production of carbon from bagasse. In 1891 Weinrich patented a process for the use of bagasse carbon as a filtering medium in the clarification of sugar juices and syrups. Clacher experimented with chars produced from bagasse, but arrived at no satisfactory conclusion except that the chars were hard to revivify. The more recent and the best work on this type of char is that of Coates. He has shown that bagasse char is more efficient than bone-black and it also removes iron-salts very satisfactorily. The chars produced by him were easy to revivify. The commercial production of char from bagasse is not feasible under the present prices of competitive chars in the market, unless bagasse char has some property that would justify a higher selling price than that of the more common commercial chars.

(4) *Cellulose from bagasse*—In more recent years alpha-cellulose pulp has appeared on the market. It is defined as that part of cellulose which does not dissolve in 17·8 per cent. caustic soda solution. This is purely an arbitrary standard. The so-called alpha-cellulose now on the market is characterized by a high alpha-cellulose content and a very white colour.

The object in any process for the production of alpha-cellulose from bagasse is to remove as much of the pith and impurities as possible without changing the fibre to any appreciable extent. This has to be done at a cost that will make the selling price compare favourably with that of the alpha-cellulose wood pulps of the same quality.

Dry whole bagasse contains about 45 per cent. alpha-cellulose. The alpha-cellulose content has to be increased to at least 90 per cent. in any practical process, which uses such material. In addition to this the ash content, Cu number, phloroglucinol absorption value, and other standards of comparison have to be within certain limits. Also the physical properties, particularly strength, have to be suitable. Practically all cellulose authorities state that the strength of the final material in artificial silk production is directly proportional to the strength of the alpha-cellulose used as raw material. This is the chief reason why an alpha-cellulose made from bagasse pith would have very little value for this type of work. The higher the alpha-cellulose content of a given pulp, the more desirable it will be in cellulose work. The market price of cellulose is also directly proportional to the alpha-cellulose content.

The first patent for the production of alpha-cellulose from bagasse was that of De La Camara and Egana. It was rather vague and unimportant. The next patents were those of Valet. The process consists briefly in boiling the bagasse in an open digester with 3 to 5 per cent. calcium hydroxide solution, cooking under pressure of 2 to 4 atmospheres with a solution containing about 6 per cent. caustic soda solution, 1 to 2 per cent. caustic potash, and 2 to 3 per cent. sodium hyposulphite for 4 to 6 hours, washing and boiling with 2 to 3 per cent. pure fat or oil soap for ½ an hour, and then washing the alpha-cellulose repeatedly with water and steam, and then drying the product. The pith and fibre are separated before this treatment. The product is known as "Celubagas". It has an alpha-cellulose content of about 88 per cent. which would compare with that of an average sulphite wood pulp. The recovery of chemicals is not mentioned. The process has the disadvantage of using costly pressure cooking apparatus, the product not being of a very high alpha-cellulose content, consumption of large amounts of steam, and the non-recovery of chemicals. All these factors will make the cost of production too high.

The Ramar patents claim the digestion of bagasse under pressure with neutral chemicals. No separation of the fibre and the pith is made. The process is not feasible since the pith content would not be reduced very much, and as a result a product will be obtained that would approach a poor grade of paper rather than a high grade of alpha-cellulose pulp.

Various mechanical separating and purifying processes have been patented. In one such process the fibre and pith are separated by a stream of water. The process is not of great importance, for the separation is not very successful and therefore the alpha-cellulose content of the product is not very much higher than that of the original bagasse.

Darling's patent claim—shredding and cleansing the bagasse, then digesting in hot water at 10 lb. pressure, drawing the solution off, hydrolysing the mass usually with sulphuric acid, washing and treating with dilute caustic soda solution under heat and low pressure. The process has some merit but the treatment is too mild. Bagasse requires more drastic treatment, and further more the heat consumption would be prohibitive.

Imary's patent deals with the digestion of cellulose free from lignin. Bagasse is not free from lignin, but the process could be used. The patent claims cooking of the bagasse at a low temperature of 45°C with a solution of alkaline earth hypochlorite containing 2 per cent. available chlorine. This solution oxidises the lignin, the solution is maintained slightly alkaline with calcium hydroxide. The process would not remove enough impurities in one step. In fact, it is doubtful whether or not the bagasse would be changed to any appreciable extent at that low temperature.

Horn claims in his patent—cooking various fibrous materials such as bagasse, straw, grass, wood, etc., simultaneously by introduction of steam into the digester containing the bagasse in contact with sodium chloride solution, passing an electric current through the solution, while cooking is in process, addition of lime and soda ash in the final stages of the cooking process, and draining and drying the pulp. The process seems practicable but it is doubtful whether any appreciable alkali content would be noticed unless the current used in the electrolysis is very large. The cost of equipment would also involve a large outlay. In one respect it is a very good process that bleaching and digesting are carried on simultaneously.

De La Rosa's process is briefly—boiling of bagasse with 0·5 to 1 per cent, of sulphur at 160° to 18°C from 20 minutes to 3 hours, drawing off the liquor, digestion with 2 to 10 per cent. NaOH or KOH at 160° to 170°C for ½ to 5 hours, and draining and drying of the resultant pulp. No claim is made for bleaching the pulp for it is stated that the pulp needs no bleaching. This is probably not true. For the usual pulp of high alpha-cellulose content (94 per cent.) does require bleaching, whereas the pulp produced from this process would not contain over 90 per cent. alpha-cellulose. No claim is made for the recovery of the chemicals. This fact would make the pulp too costly. It is possible that the chemicals could be very easily recovered. A second treatment would be necessary in order to obtain a high grade pulp (95 per cent.).

McQuistons and Van Loeseck's patent claims—treating bagasse fibre after mechanical separation with brine (sea water) in conjunction with sodium hydroxide under about 30 lb. pressure for 2 hours, washing and bleaching the pulp with calcium hypochlorite, then washing and treating with hydrochloric or other suitable acid, finally washing and drying the pulp. Claim is also made for the recovery of the alkali. This process has very good possibilities, although the efficiency of the NaOH recovery would have to be high in order to make the process paying. The cost of the bleaching would also be a big factor in the expenses of production. The process uses sea water for some unknown reason. Apparently there is no advantage in using sea water unless pure water is not available.

The work of Lynch and Goss is the most outstanding in many respects. The process studied was the nitric acid pulping process. This process is now used in Germany in the production of cellulose from beechwood. In the experiments bagasse was treated with five times its weight of 5 per cent. nitric acid at 80°C for one hour. The vessel used was open tank. The product was thoroughly washed and digested at boiling temperature in 2 per cent. NaOH solution for 30 to 40 minutes. The pulp was then washed thoroughly to remove all the alkali. Residual alkali on the fibre would result in an undesirable high ash content.

The pulp produced was very easily bleached with a very low consumption of chlorine. The alpha-cellulose content was from 86·1 to 92·5 per cent. The high soda-soluble value that resulted was probably due to the solution of very small fibres. The resulting product was then treated with 9 per cent. caustic soda solution for one hour at 100°C. The alpha-cellulose content was thus increased to an average of 95 per cent. This solution was recovered and diluted and used over in the previous digestion. The 2 per cent. caustic soda solution used in the first alkali digestion was also recovered. A total recovery of 70 per cent. of alkali was thus obtained.

	Soda soluble	Ash	Alpha-cellulose	Market price
				$
Wood pulp no. 1 ..	About 15 per cent.	0·4 per cent.	86–89 per cent.	88
Wood pulp no. 2 ..	Under 12 ,,	Under 0·4 ,,	At least 93 ,,	145
Bagasse pulp ..	5·0 to 11·5 ,,	0·2 ,,	95 ,,	.
				Per ton

The above table shows clearly that the bagasse pulp produced by this process will compare very favourably with the two commercial alpha-cellulose on the market. These two pulps are well known brands used by the Viscose rayon industry at the present time. The cost of the acid would be about $15·00 per ton of alpha-cellulose (with a 70 per cent. recovery). A yield of 32 to 33 per cent. on the weight of dry bagasse was obtained. This would make the raw material cost about 15 dollars per ton of alpha-cellulose. The advantages of the process are :—Open tanks are used instead of pressure digesters; no power is required except in the third step and that too is very little; the heat consumption is low for the charge is heated in the second step at 100°C. for one hour and in the third step for only 40 minutes.

This process is the best of the existing processes for four reasons :

(1) A high grade of alpha-cellulose pulp, which would compare very favourably with pulp now on the market, is produced; (2) the cost of production is low enough to give a good margin of profit in commercial production; (3) the process is not burdened with a patent; (4) no mechanical separation of the pith and fibre is necessary. The only drawback is that the tanks to be used must be of acid resistant material.

It is doubtful whether any of the patents involving the production of alpha-cellulose from bagasse are of any commercial value so far. It would involve quite a bit of investment and research to make even the above-mentioned process commercially successful, but the investment will pay good returns in the end.

(5) *As filtering medium*—The use of bagasse as a filtering medium was patented as early as 1883. Since that time other patents too have been issued. Weinrich advocated the use of bagacillo by adding it to the limed juice. In Egypt bagasse is used at present as a filtering medium with marked success on account of low labour costs in that country. Bagasse filters entail large labour costs due to the charging and discharging of the bagasse from the filters.

(6) *As a feed-stuff*—Bagasse has been patented as feed-stuff by various investigators. Walker heated the bagasse under pressure with dilute hydrochloric acid to effect hydrolysis and also to break up the incrusting substances associated with the fibre. The excess acid was neutralized with caustic soda. It is not clear from the patent whether the product was fixed with some other feed-stuff before being fed to the cattle or used as such.

Fucich patented the use of dry finely divided bagasse mixed with molasses. Cox's patent covers the use of dry bagasse, cocoanut residues, and molasses. In another patent the bagasse is mixed with molasses and compressed into briquettes.

(7) *As a fertilizer*—In the last two decades numerous investigators have worked on the problem of making a good fertilizer from bagasse. As early as 1900 Thompson obtained a patent for the production of a fertilizer from bagasse. The decomposition of bagasse by bacteria, with the object in view of forming a nitrogenous fertilizer therefrom, has also been investigated. The fertilizing value of the product obtained was at best not very high and the cost of production was rather out of proportion.

(8) *Paper from bagasse*—Barry in 1838 patented a process for the production of bagasse paper. This shows that even at that early date the production of paper from bagasse was being considered. A German chemist in 1896 stated as a result of his researches: "The repeated failures of enterprises for making paper from bagasse in tropical countries are attributable to industrial and economic difficulties and not to the nature of the fibre." This statement is not altogether true, for if whole bagasse is used, a brittle rattly paper of low grade is produced due to the pith content of the fibre. Various other patents were issued in the next few years. In one of these patents from 5 to 10 per cent. petroleum was added during the cooking process, the advantage of which is not clear. In 1909 Prinson Geerligs stated that the commercial production of bagasse paper was not economically possible. About 1908 a pulp from bagasse, para grass, and bamboo was produced commercially in Trinidad; but price competition was too great and the venture failed. In 1910 in Lima—Brazil was erected a plant for the production of paper from bagasse. The paper produced contained from 6 to 7 per cent. of waste rags. It was a low grade wrapping paper. This venture also failed.

About this very time various experimenters stated, as a result of their researches, that only wrapping paper could be produced from whole

bagasse. Von Possaner also showed that if a paper of good quality was desired separation of the pith from the fibre was necessary. In 1911, in Costa Rica, an inferior grade of wrapping paper was produced from bagasse and banana leaves, but could not stay long enough in the market.

In the patents of McMullen and Lee paper was produced from bagasse fibre only. The fibre was separated from the pith by mechanical means. Lee's patent specifies washing and digesting in 14 per cent. NaOH solution for 8 hours under 40 lb. pressure. The process has never been tested commercially.

In 1914, a small paper mill, which produced wrapping paper only, was erected at Preston, Cuba. Calcium chloride was used in digesting the pulp. The process was under the supervision of the University of Wisconsin laboratories. It worked for a short time and finally stopped.

McRae's patent claims boiling the bagasse with live steam in the lime solution, agitating and further washing to remove the pithy matter, then disintegrating and drawing off the water. The bagasse would not be altered much by such a mild treatment and the paper that could be produced by this process would be of a very poor grade. Marsden's process specifies the retting of bagasse with hot or cold water for a long period, then shredding and subjecting to a steam pressure of 10 to 40 lb., draining and subjecting to a still higher pressure and agitating. The product was supposed to be suitable for high grade paper, gun cotton, etc. It is questionable whether it could make anything but a low grade wrapping paper. Eckart's patents deal with the production of asphaltic milch paper from bagasse. The process is a success. It combines ingenuity and a use for the product in a field that does not require a very high grade of paper. In the production of the paper 40 per cent. wood-pulp was used in most cases. The process consists in impregnating the finished heavy paper with asphalt. Fortunately, the use of milch paper was also patented. This is the reason why the process has a monopoly in that particular field.

Marsden proposed the hydrolysing of bagasse to produce glucose from the pith, the fibre being used for paper making. The cost of production of the glucose and the paper would not make the process feasible.

In 1919 two prominent paper authorities stated that the production of bagasse paper was an economical problem instead of a technical one. The researches of Maheus Matrod showed that in the production of bagasse paper about 30 per cent. yield was practicable, but the paper produced was brittle and of low strength.

Fowler and Banerjee fermented the bagasse and obtained an alcohol yield of about 8 per cent. The fibre was then pulped with caustic soda and wrapping paper was produced. Scott's process claims separating the pith and fibre by screening, beating and cooking the fibre. His claims seem to be rather vague and unimportant.

Munroe and Lathrop preserved the bagasse fibres by pressing into hard bales (sometimes with the addition of lime) that would be impervious to air. This method of preservation is a possibility, but the deterioration of the fibres would be fast. The production of bagasse paper pulp by fermentation methods is also covered by a patent of Lathrop and Munroe. Kumagawa patented the separation of bagasse pith and fibre by water-floatation, the fibre produced being used for paper production. A company was organized in 1928 in Cuba to produce paper pulp from bagasse by the De La Roza patents, but it soon disappeared from the commercial world.

Nanji specifies crushing of bagasse and treating it with dilute sulphuric acid under pressure, washing and heating with a 4 per cent. caustic soda solution at a high temperature and at a pressure of 10 atmospheres for half an hour. This process should produce a good grade of pulp, but the cost of production would be excessive.

Richter claims steeping of bagasse at room temperature in a concentrated alkali solution, diluting the alkalinity to 7—12 per cent. NaOH and cooking of the bagasse at atmospheric pressure. The process would use a large amount of caustic soda, but the heat consumption would be very low. This may more than offset the extra alkali cost. The quality of the pulp produced would also be questionable.

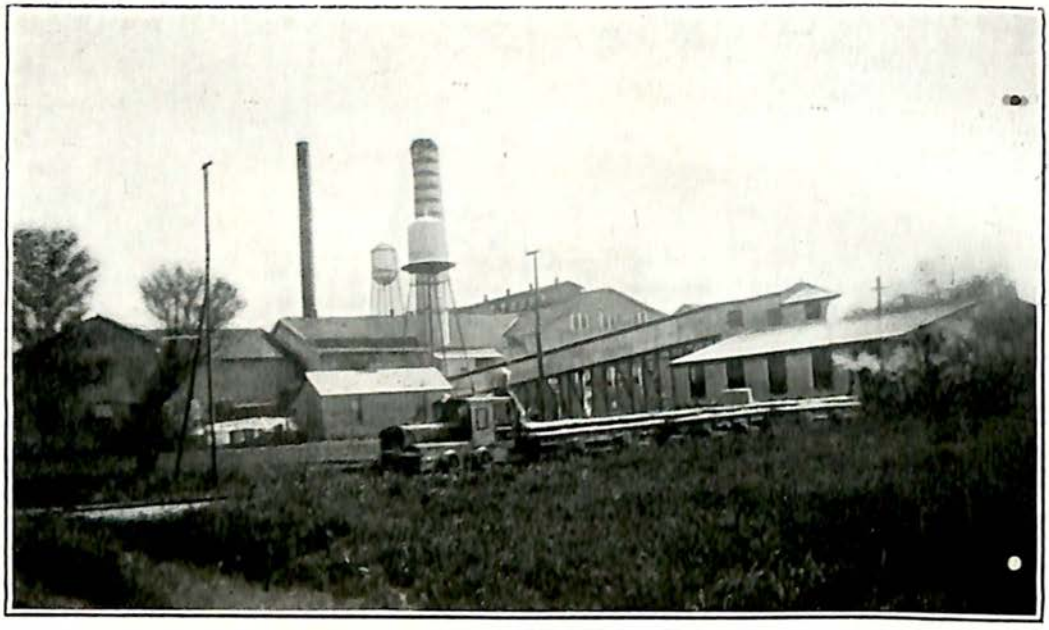
It will be clear from what has been said above that it is technically possible to produce paper from bagasse, but at the present prices of woodpulp it would not be a commercial success. Failure has marked all the efforts to produce ordinary paper pulp from bagasse. Economic difficulties are the chief reason why the production has not been successful anywhere. Bagasse requires large heat and chemicals consumption to produce a satisfactory grade of paper. If the bagasse is not properly treated a poor paper of undesirable physical properties is produced. The addition of some other pulp is also essential in making a good grade of paper from bagasse.

(9) *Brick from bagasse*—A unique use of bagasse is the formation of bricks using bagasse as binder. A very satisfactory brick was produced by the United Fruit Co., at Preston, Cuba.

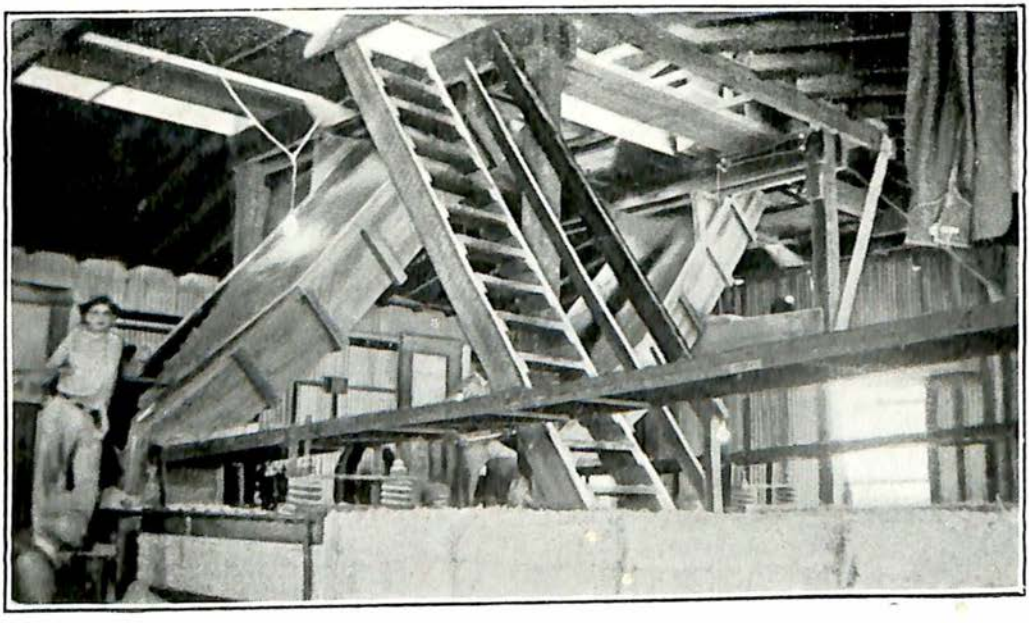
(10) *Other uses of bagasse*—Lee's patent covering the production of waxes from bagasse would be a very costly process. The wax that would be produced will be of low grade and small volume.

The formation of a fire-proof insulating material by the addition of ammonium chloride, zinc sulphate, magnesium sulphate, or sodium silicate has also been patented. This is a logical use if the product can be marketed.

The destructive distillation of bagasse has also been considered. The products are acetic acid, carbondioxide, and carbonmonoxide.



Bagasse Carrier from the factory to the Bailing House at Cinclare Central, Louisiana



Bagasse Baler at the Cinclare Central, Louisiana

Acid hydrolysis is unimportant, as the yields of reducing sugars (mostly Xylose) were too small.

The hydrolysis of bagasse to produce fatty acids, carbonic acid, and hydrogen has also been studied without any hopes of its being a commercial possibility.

Norbury, Owen, Bennett, Denson, and Arnstein have investigated the effect of bagasse on the yield of alcohol by fermentation methods. A marked increase in the percentage yield was noted. Owen suggested that the bagasse can be used for fibre-board manufacture after the fermentation process.

The use of bagasse as filler for explosives has also been patented. In Swint's patent the use of the untreated bagasse impregnated with the liquid high explosive (ammonium nitrate) is claimed. In Babcock's patent the ground bagasse is swollen and digested with water, then impregnated with the liquid explosive. This use of bagasse has some merit.

Smyser claims digesting the whole bagasse with an alkali (NaOH), adding sulphuric acid to precipitate the resinous constituents, drawing off and washing and drying the pulp, then adding an alkali substance (CaO) and moulding the product under heat and pressure. A high grade moulded product is claimed, which may find use in the making of building panels. It will have to be produced at a cost lower than that of the products now on the market in that field.

COMMERCIALLY SUCCESSFUL USES OF BAGASSE BEING MADE IN OTHER COUNTRIES

It has been mentioned in the earlier part of this chapter that the first and the most successful utilization of bagasse was made by the Celotex Company of U. S. A. in 1922, in the manufacture of fibre-board. This company started operations by producing 18 million square feet of board from only one machine in the first year and within a period of 7 years of its existence its production rose to 500 million sq. feet of board from seven machines.

The success of this company attracted the attention of the industrialists in Australia and a fibre-board plant, working on similar lines, was started there in 1926 and is working successfully.

Another plant working on the Celo-tex lines is in operation in Hawaiian islands since 1928.

It may be interesting to give a short account of the different processes involved in the manufacture of fibre-board from bagasse:

Bagasse purchases—All bagasse is purchased from the sugar mill on standard contracts that permit the buying of fuel for the power requirements of the factory and allow for a reasonable profit besides.

Baling, storage, transportation, and preservation—To collect the bagasse it is necessary to install baling stations, which are erected on land leased from the sugar companies. The conveyor from the sugar mill passes directly over the balers and discharges the bagasse into a large hopper connected to the feed chamber of the baler. The bales are all of the standard size : $22'' \times 17'' \times 32''$. These are then transported by trollies for storage in the stacks. Each stack is 100 ft. long, 60 ft. wide, and 30 ft. high, containing about 500 tons of fibre on the dry basis. Originally the piles were uncovered but in recent years galvanized iron panels 10 feet square are laid on the tops of the piles and fastened down by iron spikes 3 feet long driven into the bales.

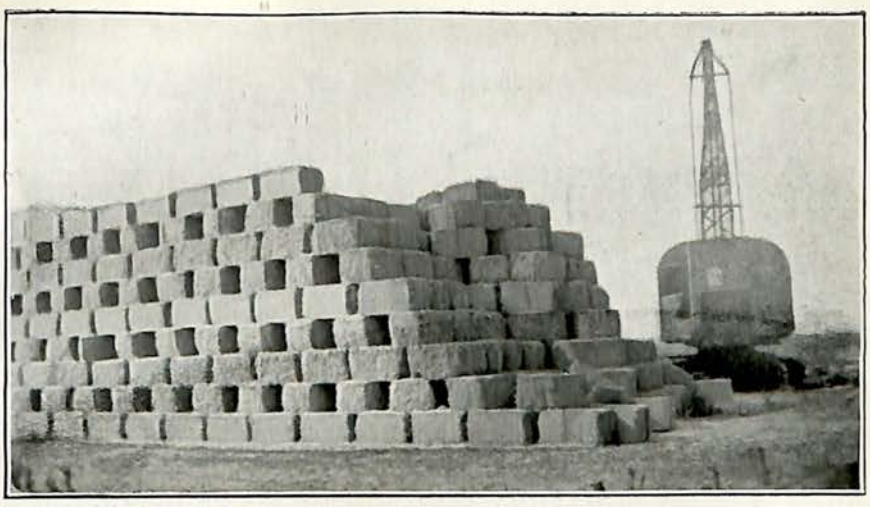
Much research work had to be done on the problem of preservation of the fibre. A number of patents have been taken. Boric acid powder is at present the chief chemical employed by the Celo-tex Company. This is sprinkled on the exposed parts of the stack, at the rate of about 500 lb. per stack. The bales in the stack are arranged in such a way as to allow a free access of air throughout the entire stack.

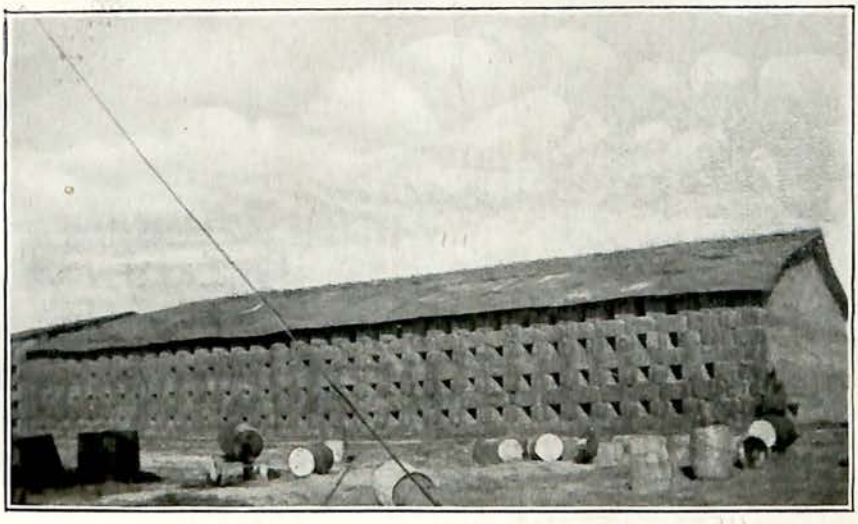
Raw material handling at the fibre-board plant—Baled bagasse is brought to the plant unloading platform in the railway wagons. These are then broken open by hand. The half or quarter bales are then conveyed on an endless rubber belt into the cooker room and dropped into one of the 16 rotary digesters, each 14 feet in diameter.

Cooking—The purpose of the cooking is threefold—(1) to get the fibres into a pliable, flexible condition so that they will respond to the rapidly moving knives of the various refining engines without breaking crosswise like tinder, (2) to loosen up the incrusting material, dissolve out the soluble matter and break down the easily hydrolysable gums from the fibre, and (3) lastly to sterilize the fibre.

Some time back the digesters used to be partly filled with a buffered cooking solution which prevented too great an increase in acidity of the cooking liquor and thus maintained the strength of the fibres. The use of buffered cooking solution has lately been given up and water alone is found to serve the same purpose quite satisfactorily. The cooking is done at super-atmospheric pressures depending on the age of the bagasse and on the variety of the cane, and for a time which is likewise regulated by these conditions. It is also regulated to some extent by the quality of the board intended to be produced.

The fibre from a cook is dropped into a tank from which it is pumped to the wet shredders. The consistency at which bagasse is pumped is about 2 to 3 per cent. which from the paper maker's point of view is very low. The action of the wet swing-hammer shredders is to break up the large fibre bundles so that the washing can be efficient. The size of the hammers, size of holes in the plates, and the revolutions per minute, etc. of these shredders are adjusted to the type of the product being manufactured.





Bagasse Stacking at the Reserve Central, Louisiana

From the wet shredders the fibre passes to rotary washers of Celotex design where the cooking liquors, dirt and a certain amount of pith are washed out. From the washers the fibre goes into half stock chests, while the washings pass through the pith recovery plant. The pith so recovered is sold to the explosive manufacturers. The half stock chests in use today are 70 feet long, 20 feet wide, and 20 feet deep, having agitators with great vertical sweeping arms set on horizontal shafts. These large chests help in levelling out the irregularities in the stock.

Water-proofing—Into the half stock chests are put the sizing agents, the most common of which being the paper maker's Rosin and Alum. The fibre from the half chests passes through three clafins with occasionally a jordan in addition, to bring it to its final optimum condition of fibre size. These refiners are fitted with special fillings, which have been gradually developed by the Celo-tex company. After passing the final refining units the fibre is pumped to the large machine stock chests and from there to the board-forming machines.

Board Machine—In this operation the pulp is changed from a liquid into a damp board of uniform thickness and continuous length. This is accomplished on specially designed machine which are composed of two distinct parts—the mold rolls and the presses. There are two mold rolls on each machine, 6 feet in diameter and 13 feet long, covered with wire mesh and together forming the front end of a vat into which the thin pulp is admitted. These rolls rotate towards each other acting like filters. The water drains out through the wire mesh and a thick layer of pulp builds up on the wire surfaces. The rolls are so designed that the sheet is not laminated but is felted together. After leaving the mold rolls this thick seggy sheet is carried between the heavy felts through the presses which successively express the free water until the sheet finally emerges to go into the drier with a moisture content of 50 to 55 per cent. The thickness of the sheet and its uniformity of felting are controlled by dilution of the stock flowing to the mold rolls, and by its velocity.

Drying—The moist board then passes into the driers. The Celotex Co. designed its own driers. These are chambers about 1,000 feet long heated by natural gas to a temperature of above 330°F. By placing two or more board machines in tandem and running the sheets produced by the rear machine under the front machines, it is possible to pass two or more continuous sheets through a drier at one time. Large multivane fans in the driers provide constant circulation of vapours. No fresh air is admitted in the driers as water vapour is preferable to air as a circulating medium, because of its being a stable gas under operating conditions and having higher specific heat, it has no tendency to brown or char the board.

Seasoning and sawing—The board comes from the drier in a bone-dry condition and will take up about 8 per cent. water in coming to equilibrium with normal atmospheric conditions. It is therefore sprayed with water, in order to season it, as it emerges from the drier. After being sprinkled with water it is cut automatically into desired lengths for the market.

It was pointed out in the beginning that Celo-tex contains about 17 per cent. of waste paper pulp. This is added in requisite quantities in the half stock chests. In order to safeguard the board from the attack of termites, white ants, etc., it is necessary to add a certain amount of well-known insecticides (termite proof) to the material. This is done just before the material enters the board machine.

Uses of Celo-tex—An examination of the sales record of the Celo-tex Company will show that in 1922, when the factory started working, the total sales amounted to about 19 million square feet but rose up to 500 million square feet by the year 1930. One division of the research and development branch of the company is devoted to finding sales outlets for the products and to developing the specifications of application for such uses. The various uses developed so far are as follows :

Building Construction—Sheathing, plaster base; base for wall paper, plastic paints, etc.; interior finish; roof insulation; sound absorption and quieting of offices, auditoriums, etc.; sound insulation floors and partitions; carpet lining; linoleum base; exterior finish camps and cabins.

Industrial uses—Railroad refrigerator cars; mechanical and ice refrigerator; ice cream, bottle dispensary, and similar cabinets; Radio baffles, cabinet linings, housings; Cores for wood, steel, resin veneers; Automotive dash pads, tops, floor coverings, anti-drum; Insulated truck bodies; Aircraft and hangers; Expansion joints, concrete Deadening machine vibration; Special packaging, and Signs.

Miscellaneous uses—Blackboards; Bulletin Boards, pipe gaskets, mirror backs, tennis-court surfaces, whaling gun wads, art screens, oil filters, archery targets, radiator shields and table pads.

Besides the manufacture of fibre board, there is hardly any other commercially successful venture, worth mentioning which utilizes bagasse on a big scale, but the possibilities of other industrial uses for this form of cellulose are being intensively studied at present on a semi-commercial scale and may result in the development of some new industry in the near future.

Hard Panel Board—During the last year or so semi-commercial work in the laboratories of the Celo-tex Company have resulted in the production of a superior hard panel board made entirely from bagasse.

This product has a highly polished, very uniform surface, is very strong, and is sure to find wide industrial use. It is now being sold in small volume. A plant will probably be built up in Florida for the manufacture of this article in large volume.

Paper—It has been known for years that satisfactory paper of certain kinds could be manufactured from bagasse, but hitherto such processes have not been commercially sound. The major item has been the cost of bagasse. The handling problems of this fibre have been solved by the Celo-tex Company and the fibre costs are being materially lowered for this group of industries. The average cost of freight to the mill has now been brought down to 85 cents. and of loading into cars to 29·8 cents. per ton of dry fibre. In 1928 the company purchased the Chas Boldt Paper Mill at New Iberia Louisiana, largely as a plant where developments could be carried on. This plant is now being operated, supplying its regular line of products and the replacement of bagasse in various furnaces is proceeding satisfactorily. This mill is now supplying all the wrappings for the Celo-tex products. One of the outstanding developments so far is that of corrugated paper. Investigations under way cover the use of bagasse for a variety of paper products, but it is proposed to announce these only after the semi-commercial scale work is complete.

Bagasse and the Resin industry—A product of considerable interest is "Bagasse Felt" which is manufactured on a paper machine from fibres much like those in Celo-tex. This sheet runs from 25 to 90 caliper. This type of felt has distinct advantage as a base for impregnation in the manufacture of synthetic-resin laminated articles. The fibres can be so handled that the amount of resin absorbed is controlled and articles containing as low as 10 per cent. resin can be satisfactorily made. The field for this felt seems to be very large, since it will be one of the chief factors in bringing about lower costs in the plastic field.

The use of bagasse fibre of various sizes, pith, and ground bagasse in making moulded resin products is showing likewise great promise. The advantage seems to be freedom from resins, uniformity of product, control of resin absorption, and the necessity for the long, strong fibres in certain products.

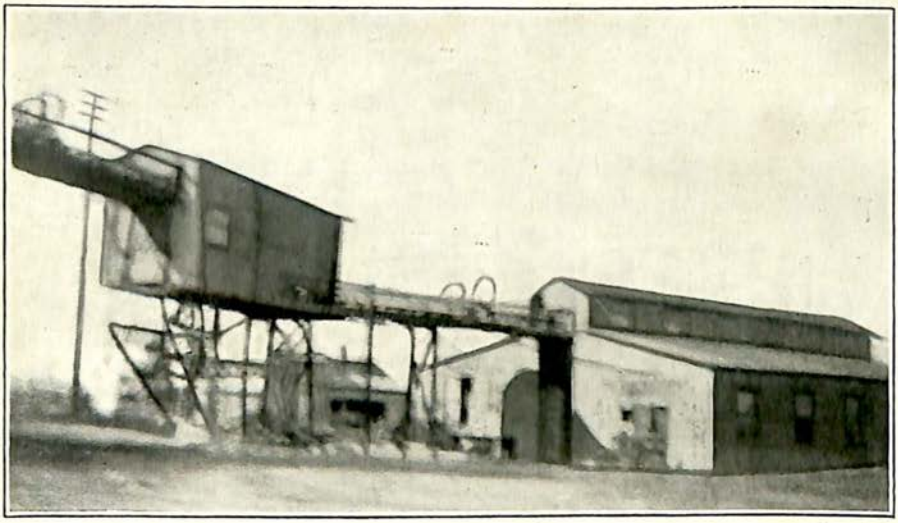
RECOMMENDATIONS FOR INDIA IN REGARD TO BAGASSE UTILIZATION

India and the fibre board industry—To one familiar with the properties of bagasse fibre-board and the climatic conditions obtained in India, the possibilities of the development of this industry should appear very great. The writer is of opinion that if an insulation board could be available in India at prices below those of ordinary timber, it would certainly have a big future market, at least among the middle class Indians. Even under the

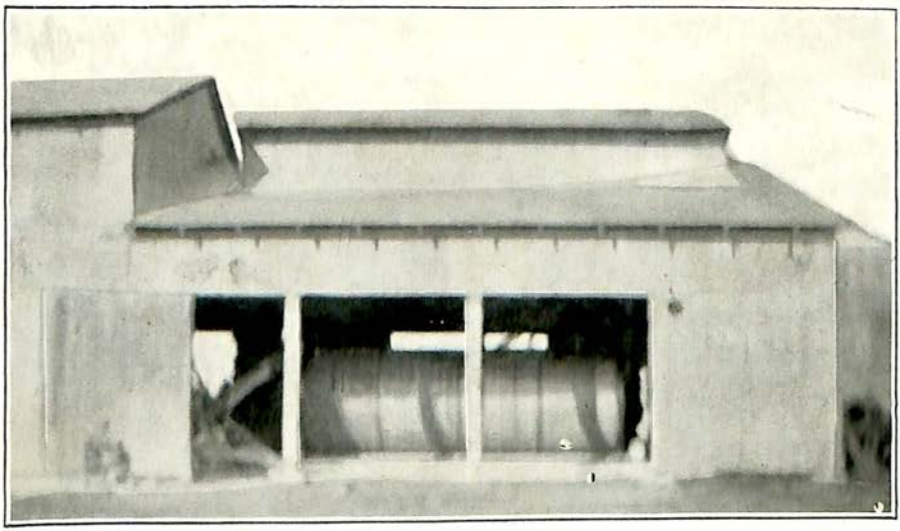
present conditions, India imports about one million square feet of fibre-board from the Celo-tex Company every year. The authorities of the Celo-tex Company themselves admitted to the writer that their Indian market could be considerably increased, if they could afford to sell their product at cheaper rates than they were able to do at present. The Celo-tex Company, a few years back, sent out their experts to the different sugar producing countries in order to report if it would be worth while for this concern to start its own or allied concerns in other territories for the manufacture of Celo-tex. The reports received for the various countries showed that there would hardly be any reduction in the present costs of manufacturing the product in Louisiana and consequently the idea was given up. For calculation purposes the cost of manufacturing 7/16″ thick bagasse fibre-board is taken as 15 dollars per 1,000 square feet although the manufacturing cost in the Celo-tex Company is only 13 dollars. The selling price of Celo-tex in the United States is about 30 dollars per 1,000 square feet. The writer was told by Mr. T. B. Munroe, the Vice-President of the Company, that they could not afford to sell it much below this price as the cost of marketing the product were almost as much as the cost of manufacturing the board. In his opinion the key of the industry lay in marketing the board and not so much in manufacturing it, as any country producing sugarcane could certainly manufacture bagasse board at a cost not exceeding 15 dollars per 1,000 square feet but it would not be an easy matter to market the product with profit. He was consequently very doubtful if the efforts to establish an Indian bagasse-board industry would be crowned with success.

Behind every success there are clean cut causes and there is no reason to think why the lines of development followed by a successful industry in one country cannot be duplicated in another with the same market success. The success of the Celo-tex Company has been due to leadership and enterprise in its organizers, by the possession of the best experience in all departments of the industry as it then existed, and a very clear recognition that the foundations for a successful business must be a careful research before action. The strides, then, which the industry has made so far are wholly logical and expected, the element of chance playing little or no part.

It must be recognized that the British possessions of the world are the biggest customers of the Celo-tex products, and import this material at excessive shipment charges to their territories from Louisiana. The only bagasse-board plant in the whole of the British Empire is in Australia, which is so far away from the markets of the world that it is seriously handicapped in competition on account of heavy freights. The location of the plant in India will be central and the writer is hopeful that it will soon develop an export trade with countries where the quality of its products and the prices are found suitable.



Bagasse Conveyor and Screener at the Reserve Central, Louisiana



Bagasse Drier at the Reserve Central, Louisiana

In order to give a lead in this direction the Imperial Council of Agricultural Research, India, should undertake to finance the research work that can be satisfactorily carried out by the co-operation of the Sugar Research Laboratories at the Harcourt Butler Technological Institute, Cawnpore, and the Forest Research Institute, Dehra Dun, at no big expense. The results of these investigations may prove sufficiently attractive to some enterprising party, who may be encouraged to take it up commercially.

Alpha-Cellulose in India—The manufacture of alpha-cellulose by the process of Lynch and Goss has satisfactorily passed those laboratory stages from which it can be safely taken up on a commercial scale. In the absence of any Rayon industry so far in India hardly any use could be made of bagasse for this purpose. If any industrialist in India starts up the Rayon industry in the near future, there is bound to be a good market for the manufacture of alpha-cellulose from bagasse, as the alpha-cellulose so made will compete very favourably with any of the imported alpha-celluloses that would be required for the Rayon industry.

As a feed stuff—In the United States of America the production of cattle feed from bagasse is not considered a promising outlet for surplus bagasse on account of the fact that there is no scarcity of other cheap cattle-feeds and the cost of producing bagasse cattle-feed works out above that of other common feeds on the market. In spite of this fact some of the progressive planters in Louisiana have realized the value of bagasse as a cattle-feed and have been feeding the same to their mules, heifers, and dairy cattle for over three years with very satisfactory results. The writer has personally seen the above cattle at Raceland, at Reserve Plantations, and at the Belle Pointe Dairy in Louisiana. They were at least as healthy as those fed on other feeds. The following method is adopted for making the cattle-feed from bagasse at the Reserve Central in Louisiana.

The bagasse coming out from the mills on the carrier is first passed over a Rotex screen (model 421) supplied by the Orvelle Simpson Co. of Cincinatti, Ohio, whereby the finer pith is separated from the coarse fibres. The coarse fibres go to the Baling plant of the Celo-tex Company, while the finer screenings are passed on to a special bagasse drier. The bagasse drier is a cylindrical unit about 20 feet long and 7 feet in diameter. It is fired by natural gas and has cyclonic exhaust arrangements at the rear end—supplied by Clarage Fan Co. (model 21) of Kalamazoo, Mich. The capacity of the drying plant is 30 tons of bagasse screenings per day. The moisture content of the dried screenings is about 5 per cent. These screenings have been found to be a valuable feed for the cattle. Its nitrogen free extract figure compares favourably with such feed materials as Soy bean straw, oat

hay, and dried brewer's grain. The figure for fat content compares favourably with oat hulls, and corn fodder (stalks).

In the feed plant of the Reserve Central a balanced feed for the mules is prepared by mixing 8 parts of bagasse screenings, 6 parts of corn, 3 parts cottonseed meal, and 11 parts of molasses. Twenty-eight lb. of this feed are given to each adult mule per day in addition to 7 lb. of Alafa hay. This practice has been going on for over three years and the mules have not only shown steady health but have decidedly been better in all respects. They have, however, to be started on this feed very gradually, else they might develop symptoms of indigestion. The Godchaux Brothers also own the Belle Pointe Dairy containing 361 cattle, including some of the best milk cows in Louisiana. The bagasse screening have also been tried with satisfactory results as a feed for dairy cattle. A ration of 33 parts bagasse screenings, 35 parts of molasses, and 30 parts of cottonseed meal—having approximately 11 per cent. Protein and 46 per cent. Nitrogen free extract—is being fed to dairy cows and heifers in addition to hay and pasture.

In a country like India with a very large number of cattle heads, with an ever existing fodder problem, and with a great scarcity of pasture lands, it is reasonable to think that the surplus bagasse could be most economically utilized to solve this problem of the ryots effectively. Mr. W. P. Naquin of the Honokata Sugar Company, Haina, Hawaii, strongly advocates the use of fine bagasse for cattle feed purposes as very promising. The only equipment necessary in a sugar factory would be to put up a screen for separating the pithy portions from the coarse fibres. Under the climatic conditions prevailing in India during the grinding season, it would not be necessary to instal a Dryer for the removal of the moisture from the screenings, and even if it is, it will surely be a profitable investment.

The writer has often been told that there are great apprehensions in the Indian mind for utilizing a cattle-feed of the type he has advocated above. He will, however, admit that some time will certainly have to be spent to get over the conservative ideas of the ryot before the use of such a feed could be made popular, but there is no doubt that a little intelligent education and strenuous but sympathetic work in the villages by the Agricultural Departments and the Imperial Council of Agricultural Research would prove that this, like other pessimistic assertions concerning the Indian agriculturist, is not necessarily true.

The sugar factories should co-operate with the above departments in manufacturing such feeds and distributing it either free or at nominal prices, in the beginning, to make them popular. A good beginning could be made by a factory owner to supply this feed in sufficient quantity to a Gaushala or other philanthropic dairy. Attempts should be made to try these feeds on one or more animals in the Agricultural

and Government Military dairies, as well as on the mules and horses in the Military Departments of the Government and the Native States.

When these people, after satisfactory trials will find this feed suitable and start using it there is no doubt that a big cattle-feed industry would develop in India in no time. Bearing the Indian conditions in mind, the writer would give priority to this method of utilizing the surplus bagasse, as he considers it not only a solution for the immediate utilization of the by-products of the sugar industry (surplus bagasse and molasses) but also sowing the seed of a future big industry, which would go to a great extent in reducing the sufferage of the cattle life in this thickly populated land.

Activated Compost from Bagasse—Taking into consideration the condition of the bagasse as it comes out from the mills, the writer is inclined to think that it will make a satisfactory raw material for the making of Activated Compost for subsequent use as manure for the cane fields. The advantages of this raw material are :

It is available in large quantities at centralized places so that the cost of collection is entirely eliminated. Since the quantities available are very large, it is possible to handle the process by mechanical means instead of manual labour, thus also reducing the costs.

The process must, however, be tested on a semi-commercial scale to get definite information about the fertilizing value of the final product, and how long it takes for complete decomposition. The writer would suggest that experiments in this direction should be carried out in the Sugar Research Laboratories under the Sugar Technologist at Cawnpore, and field trials be made in conjunction with the Agricultural College.

CHAPTER IV

Molasses

Cane molasses is the product left after separating the sugar from massecuite melada, mush sugar or concrete, and contains not more than 25 per cent. water and not more than 5 per cent. of ash. There are three different classes of molasses, depending upon the degree to which they have been exhausted of sucrose or, more correctly, the number of times that sucrose has been removed from them by crystallization. Under this classification we have first and second molasses, and the final product known as Blackstrap. This classification is not so sharply defined under present day conditions owing to the practice of using "Cut strikes" in which a lower grade molasses is grained upon a higher purity product, making a mixed molasses, which at one time may be known as a first or at another a second molasses. In addition to the above grades of molasses we have open kettle molasses, as distinguished from the vacuum pan product.

While it is rarely difficult to determine from the chemical analysis whether a product is a cane syrup of a first molasses, it is sometimes quite a problem to differentiate between a first and second molasses, e.g. whether a fairly well exhausted second molasses is a third or final molasses. It is quite important, in many instances, to be able to differentiate between these grades in order to enforce the proper labelling of them, but there is so much over-lapping in their composition that adequate methods for their differentiation are not available. It is also questionable whether the composition of these products of their edible qualities should constitute the basis for their classification. Some years ago a serious effort was made in the United States by the Committee of Rivision of Standards of Syrups and Molasses so as to eliminate confusion and misinterpretation of their nomenclature. In endeavouring to collaborate and assist that Committee, the Laboratory staff of one of the largest packers of syrups and molasses in the country, made a careful study of all the analytical data then on file there. The results of this study of hundreds of analyses showed that the sucrose was more consistently valid as a differentiating criterion than any of the other analytical data. The results were as follows :

Sucrose—Overlapping of 0·6 per cent. of samples between first and second, and 2·5 per cent. between second and third.

Purity—Overlapping of 0·8 per cent. between first and second and 4 per cent. between second and third.

Ash—Overlapping of 32 per cent. of samples between first and second and 50 per cent. between second and third.

Saline Coefficient—Overlapping of 4 per cent. between first and second and 50 per cent. between second and third.

Ratio of Ash to Saline Coefficient—30·3 per cent. between first and second, and 50 per cent. between second and third.

The average of the analyses of the three classes of molasses from which the above ratios were reduced, are as follows :

	First molasses	Second molasses	Third molasses
	Per cent.	Per cent.	Per cent.
Sucrose	46·55	37·33	29·50
Purity	61·90	49·37	38·00
Ash	5·98	7·55	7·74
Saline Coefficient . ..	7·77	4·74	3·30
Ratio of Ash to Saline coefficient.	1·43	0·99	0·515

The above analyses were of samples on the market over 30 years ago and differ in many respects from the products obtainable at the present time. It will be seen that the ash content of molasses will average more than 5 per cent. allowable under the present standard. This standard is now generally regarded as obsolete in America, and few of the States have made any effort to enforce products to conform to it. The State of California is one of the exceptions to the rule, and there a molasses containing over 5 per cent. ash has to be labelled as Blackstrap. This standard should be changed unquestionably in order that it may conform to the composition of the products now on the market. In the analyses of hundreds of samples of cane molasses only 42 per cent. of the firsts conformed to the 5 per cent. ash limit, and only 18 per cent. of the seconds. The importance of molasses is seen when it is realized that from 15 to 25 per cent. of the sugar present in the original juice is found in the molasses. The quantity of molasses produced is about 3·5 per cent. on the weight of cane milled.

The ash of molasses contains Potash—40 to 55 per cent. Lime—6 to 12 per cent. Silica—1·5 to 3·0 per cent. Magnesia—1·5 to 4·5 per cent. Iron and Alumina—1·6 to 2·5 per cent. besides containing small quantities of chlorine, sulphates, phosphorus, carbondioxide, and sodium.

The ash is interesting because of its high potash content and very low soda content. Even in the presence of large amounts of soda salts in the soil, the sugarcane assimilates potash, if available, else it withers and dies.

The production of edible molasses in America is, as a rule, more uniform than that of syrup. Statistics for edible molasses, as distinguished from Blackstraps, show an annual production of about 8,000,000 gallons per year.

The scarcity of sugar during the War stimulated the consumption of molasses in America to a considerable extent, but did not apparently create any permanent new usages for them. When sugar again became available, the molasses were again relegated to their former place in the food supply of the nation and the world, and have remained there since. Blackstrap molasses is chiefly used for alcohol manufacture and for cattle-feed, to some extent for yeast making, and to a less extent in the manufacture of shoe blacking and in tanning. It is also used to some extent as a medium for mixing calcium arsenate as an insecticide in the control of cotton boll weevil. In some countries it has been used as a fertilizer, although its value for that purpose is still a debated question.

It is now proposed to deal with the various uses to which molasses have been put from time to time in different sugar producing countries of the world.

Utilization of Molasses

(*a*) *Recovery of Sugar from Molasses*—None of the processes used in the recovery of sugar from beet-molasses have so far been found applicable to cane-molasses. It is stated that cane-molasses cannot be so treated owing to the presence in it of a considerable quantity of invert sugar, which when treated by the Steffen's process gets decomposed by lime giving dark coloured decomposition products. One suggestion for the recovery of sucrose from canesugar molasses is to ferment it by a special yeast that acts on the invert sugar only, then to distil off the alcohol and recover sucrose from the spent wash by the Steffen's process. Apparently, there are yeasts which under carefully controlled conditions, will ferment invert sugar and leave sucrose unattacked, but it has not been possible to operate with these yeasts commercially. Work on Selective fermentation is, however, being carried on semi-commercial lines at the California Refinery under the guidance of Dr. W. L. Owen of Louisiana and may at some future date result in a commercially developed process. Experimental work on the recovery of sugar from cane-molasses was carried on for some years till 1926 by the late Dr. E. R. Watson and his associates at the H. B. Technological Institute, Cawnpore (Journal of the Indian Chemical Society, Vol. III), by a modification of the well known Battelle's process for manufacturing sugar from sugarcane. By the simplest process he succeeded in obtaining a recovery of 84 per cent. of the sugar in the molasses in the form of a syrup of 70 per cent. purity. Assuming that this syrup on boiling would give crystalline sugar and leave molasses of 40 per cent. purity, we could get 24 parts of crystalline sugar and 24 parts of molasses from 100 parts of molasses containing 40 per cent. sucrose.

If the above results could be satisfactorily duplicated in the factory, there is no doubt that the process would be adopted by all the sugar manufacturers. Unfortunately, the process has not been tried even on

the semi-commercial scale to get more reliable data from the manufacturers' point of view. It will be worth while to continue further work on this process in the Experimental Sugar Factory of the Imperial Council of Agricultural Research.

(*b*) *As a Fuel*—Molasses has occasionally been used as fuel to supplement that afforded by the bagasse. The simplest way is to let the molasses fall on to the bagasse on its way to the furnaces. It may also be atomised and burnt in special furnaces. Actual determinations by Atwater have given a calorific value of 6956 B.T.U. per lb. of dry matter or 4500 B.T.U. when the 25 per cent. water content is not removed. Air-dried wood gives from 4500 to 5000 B.T.U. so that the value obtained for molasses is about the same as that of an equal weight of wood-fuel. If the ashes are returned to the soil, most of the potash is made available as plant food. This is a very uneconomic method of utilizing the molasses and must on no account be encouraged.

(*c*) *As a Fertilizer*—Many experiments have been carried out to determine the fertilizing value of molasses. The results thus far are conflicting. One set indicates that molasses aids the nitrogen-fixing organism in their work resulting in an increase in the nitrogen content of the soil and in increased crops. Another study has shown that the continued addition of glucose to soil bacteria in vitro retards the activity of the nitrifying and ammonifying organisms and accelerates that of the denitrifying races. The truth is still to be determined.

Experimental work to determine the actual value of the molasses as a fertilizer should be carried out by the Sugar Research Laboratory in co-operation with the Agricultural College at Cawnpore.

(*d*) *As a Filler in Manufactured Products*—The use of molasses as a filler is very limited and insignificant. It is used to some extent in the leather industry and in the preparation of shoe blacking and leather dressing.

(*e*) *For Road Surfacing*—A number of patents have been issued in the past regarding the utilizing of molasses as road surfacer, but to the best of the writer's knowledge hardly anybody has been successful to popularize the use of molasses for this purpose on a big scale. The four essential points for the success of a good road surfacer are:

(1) That the composition should be perfectly liquid at the time of application.

(2) After being spread over the road, it should not melt in summer or be slippery in the rains.

(3) It should not wear away under heavy traffic.

(4) It should be cheaper than various market asphalt compositions.

The main draw back in the use of molasses for this purpose has been that the composition could not be made strong enough as not to wear away under heavy traffic.

Experiments in this direction have lately been conducted in the Sugar Research laboratory at Cawnpore by Dr. H. D. Sen and his associates, who claim to have produced a road composition which satisfies all the above requirements. The value of their work has, however, still to be tested on a larger scale. This could be easily arranged with the co-operation of the Public Works Department. If the product proves satisfactory in the trials of Engineers, this method of utilization will afford a tremendous outlet for the molasses, specially in view of the possible activities of the Indian Roads Committee in the near future.

(*f*) *Manufacture of Yeast from Molasses*—The utilization of molasses for the production of yeast is a very promising outlet in the Western countries. In the United States of America as much as 25,000,000 gallons of molasses are used per year for this purpose alone. The consumption of beet-molasses in Germany for this purpose is many times greater. The use of molasses as a source of carbohydrates for the development of the yeast cells had not been successful until 1915, when the Ammonia-molasses Process for yeast manufacture was developed by the investigations of Hayduck and Wohl. In order to utilize molasses, it is necessary to remove the material which discolours the yeast, to add sufficient mineral nutrients to give the yeast satisfactory nutrition (for it must be remembered that growth—and not fermentation—is desired in growing yeast), to make satisfactory dilutions as indicated in the work of Hayduck, and to grow the type of yeast which reproduces normally in molasses solution, without the production of alcohol. Yields of yeast as high as 200 per cent. based on the sugar have been reported.

The yeast thus produced can be used as human food as well as fodder. One pound of dried yeast contains as much food value as 3·3 lb. of meat. While meat has 75 per cent. water and 20 per cent. protein, the yeast has 8·5 per cent. water and 53 per cent. protein.

The use of molasses as a source of yeast, though a very promising outlet for other countries, is of no significance to India, as it would be almost impossible to market the yeast so produced. The Indian public have to be educated considerably before the establishment of an Yeast Industry can be contemplated.

(*g*) *The Value of Molasses as a Food for Man and Cattle*—That molasses is remarkably wholesome food is quite generally known and almost universally conceded to be true. Too much of their advertised food value, however, has been attributed merely to their sugar content, and too little to the wholesomeness and to the general salutary effect upon the digestion.[1] It is quite obvious that these products exercise a beneficial effect in human or animal nutrition, quite distinct from the energy equivalent of their carbohydrate content. While an investigation of their vitamin content seems still to be lacking, their beneficial effects when included in the diet would leave little doubt of their presence in these products. It is said that lumbermen in the Canadian

woods consume large quantities of the lowest grades of cane molasses and find that it keeps them remarkably free from the digestive disorders so commonly associated with a concentrated and monotonous diet. It is reported that in some tropical countries the native children, who during the summer months become very emaciated for lack of proper foods, become fat and vigorous during the cane milling season when they subsist largely on the juice of the sugarcane. Strange as it may seem, the taste for cane-molasses is more easily acquired than that for cane syrups. In the Northern and the Western States of America there is a much more active demand for cane molasses than for cane syrups, and in fact it is hard to develop a market for the latter product in those sections. There is unquestionably, a very prominent and persistent flavour to cane syrups which is not readily relished by those who are unfamiliar and unacquainted with these products.

In view of the fact that as much as 8 million gallons of edible molasses are produced and consumed every year in a modern country like the United States, it is logical to presume that a similar industry could be more easily developed in India producing edible molasses for human consumption. If attention is given by the sugar factories in this direction, it will go a great way in reducing the quantities of Blackstrap molasses, which are forced to be produced at the present time under the existing practice of the Indian sugar industry.

The use of blackstrap molasses as a cattle food originated with an observation by Hughes that the interior pith of sugarcane was capable of absorbing large quantities of molasses, affording a product which could be shipped in bags; this was called "molassecuit". Various other absorbents have since been used, among which may be mentioned peat, sphagnum moss, bran and various kinds of meal, beet pulp and alfalfa. There are at present some fifty or more mixed feeds on the market, all of which contain more or less molasses. The amount of such feed produced each year is roughly estimated at 2 million tons, the molasses content in which varies from 10 to 50 per cent. Molasses as such is not a complete food, since it contains only about 0·15 per cent. Nitrogen. Its food value lies in its sugar content. It is generally recognized that the salts of molasses have a distinct value in stimulating the appetite and the digestion, so that larger amounts of forage are eaten.

In the United States of America, where the number of cattle heads is many times smaller than India, the consumption of blackstrap molasses on an average is 50 million gallons per year. The writer is confident that the consumption of molasses for this purpose could be easily raised to many times the above-mentioned figure in India by suitable co-operation of the sugar factories, the Agricultural Departments and the ryots, as advocated before under bagasse as a feed-stuff.

It has recently been pointed out to the writer that the Indian blackstrap molasses, on account of careless working in some of the sugar factories, are liable to contain too much of lime and other impurities which

may have toxic effect on the nutrition of the animals which are fed on them. This drawback can be easily remedied by fixing a specification for the molasses intended to be used for this purpose. Before this is done, however, it will be necessary to carry out experimental work to decide upon a safe specification of blackstrap molasses for cattle-feed purposes. This work could be efficiently carried out in the Sugar Research Laboratory at Cawnpore.

Of the various possible outlets described in this report for dealing with surplus molasses in India, the writer is of opinion that the Imperial Council of Agricultural Research should give prior consideration to this problem of cattle-feed manufacturing and to its being made popular among the agriculturists.

The part that molasses play in the food of man and cattle is so important in the United States that a company "Molaska Corp" has quite recently been formed with the purpose of solidifying the molasses in order to reduce the transit charges as well as to make the product wholesome for handling. The Molaska Corporation has two plants—one operating at Elizabeth N. J. and the other at Cleveland OHIO—each with a capacity of solidifying 120,000 lb. of molasses per day. The product is sold in the market in powder form contained in neat card-board boxes. The process of manufacture, which is the subject of a pending patent, is a combination of open kettle and vacuum evaporation and it is claimed that the flavour and other ingredients of the liquid molasses are passed on as such in the solidified powder. The cost of solidification works out at $1\frac{1}{4}$ cents. per lb. of molasses. The dry and powered Molaska is used in the food of man and cattle, for making ice creams, cakes, pastry, and various other food preparations.

A new use has been found in the making of fire-bricks.

(*h*) *As a Source of Potash and Various Organic and Inorganic Chemicals*—Only a few years back the economic conditions made it generally recognized that the future of the American beet-sugar industry was to a great extent dependent on the profitable utilization of the molasses produced, which contained numerous valuable substances that have never been successfully recovered outside Germany. For many years that country has seen fit to veil its developments and discoveries and to maintain the strictest secrecy regarding the operation of its molasses plants. The scientific literature on the subject is practically barren, so far as the actual results achieved in Germany are concerned. In order to carry out the necessary experimental work for the American industry every possible source of information was investigated by the Bureau of Standards. After a few clues were obtained the U. S. A. Patent Office literature was searched and eventually over 1,000 German patents were uncovered on molasses utilization and allied subjects. The difficulty in locating these patents was due to the fact that they are

not listed under sugar or molasses or subjects that were known to the Bureau's investigators.

Prior to 1914 approximately one-half of the world's sugar supply was produced from sugar beets, and with the ecomomic conditions that have long prevailed in Europe it is logical to expect that all the resources of modern science would have been utilized long ago to develop methods of recovery of the valuable by-products known to exist in such large-scale production commodity as beet-molasses. Four beet-sugar utilization plants were in operation in Germany between 1914 and 1918, when two of them were destroyed. The most noted of the four German plants is known as the Dessau plant, located in the city of Dessau.

Among the various chemicals that appear to have been recovered in Germany from waste beet-molasses the following may be mentioned:

Methylamines, ammonia and ammonium Sulphate, sodium and potassium cyanides, nitrogenous bodies—such as, Betaine and glutaminic acid, alkali salts (K_2C0_3, Na_2C0_3, K_2S0_4), vegetable carbon and tar, and various minor products—such as methyl alcohol, glycerine, organic acids and esters.

The patents deal with the processes of recovery of the above chemicals as well as the equipment necessary for the same.

Hardly any work of the above type has been done anywhere on the recovery of such valuable chemicals from cane-molasses. It is very important that investigations for the recovery of such valuable products from cane-molasses be carried out at the Sugar Research Laboratory as a part of fundamental research for the improvement of the future sugar industry in India. On account of the impetus given by the investigations of the Bureau of Standards, as mentioned in the beginning of this chapter, the Eastern Alcohol Company of America in 1928 made 10,200,000 gallons of alcohol and 4,000,000 gallons of glycerine from 30,300,000 gallons of molasses. The results of such fundamental research are sure to bear fruit in India also some day.

(*i*) *Fermentation of Molasses*—That molasses is the cheapest raw material for the manufacture of alcohol is a very well established fact. It is a by-product of the sugar industry. The cost of raising, harvesting and transporting the cane or beet crop is debited to the sugar manufacturing account in the case of molasses; whereas with starchy materials the cost incidental to its raising and production are entirely borne by the starch itself. It has been stated that if the 21 million gallons of molasses produced in the island of Hawaii had all been converted into alcohol, over 9 million gallons of 90 per cent. alcohol would have been produced. A bushel of corn yields about 2·8 gallons of 90 per cent. alcohol and the average yield of corn is about 30 bushels per acre. Therefore to produce 9 million gallons of alcohol 3,248,000 bushels

of corn would be required, representing a crop from 108,000 acres—an area only 5,000 acres less than that from which the 21 million gallons of molasses are derived together with the main crop of 50,000 tons of sugar shipped. Similarly, a bushel of potatoes yields 0·73 gallons of alcohol, the average crop of potatoes being 20·5 bushels per acre. Thus for producing 9 million gallons of alcohol a crop from 60,000 acres will be required, which is 53 per cent. of the area required in Hawaii for producing the equivalent of molasses and the additional 50,000 tons of sugar.

It would be clear from the above that none of the raw materials for the manufacture of alcohol can work out cheaper than molasses. The utilization of molasses as a raw material for this purpose presents other advantages on account of the fact that the sugar is present in them in a fermentable form, and consequently it does not require any preliminary treatment such as is necessary in the case of potatoes, corn, and other starchy materials. The yield of 95 per cent. alcohol is about 75 gallons per ton of molasses.

It is interesting to note the part played by molasses in the United States of America as a raw material for the manufacture of total quantity of alcohol produced in that country each year. It may be pointed out further that almost the entire production of cane-molasses in Louisiana is utilized in the making of cattle-feed for domestic consumption, while that required for the manufacture of alcohol has to be imported from other countries.

Materials used in producing Industrial Alcohol for the year 1931—

	Per cent.
Molasses	84·76
Grains	3·75
Grain molasses, chemical mixtures, etc.	0·86
From other raw materials	0·94
Synthetically	9·69

(j) *Manufacture of Acetic Acid and Allied Products from Molasses*—We should not limit our consideration of the utilization of molasses only for the production of alcohol, which involves difficulties of Excise control, but should also find out ways and means by which molasses could be utilized for the development of other industries in India, which do not involve such complications. One of these is the conversion of molasses into Acetic Acid with the help of *Mycoderma aceti*. Most of the Acetic acid produced at the present time in the world is obtained by the destructive distillation of wood. In view of the huge amounts of molasses accumulated at the present time in India, this biochemical method of utilizing the same seems to be quite feasible. A review of the statistics of the annual imports of Acetic Acid and allied products in India during the last three years will show

that we are importing Acetic Acid to the value of Rs.4,20,000. White lead (dry)—Rs.43,880, White lead (moist)—Rs.2,43,680, lead Acetate—Rs.1,75,221, Reduced White lead—Rs.40,000, making a total of Rs.10,11,691—per year.

Taking the production of molasses in a factory crushing 400 tons of cane per day, there would be produced about 14 tons or 375 maunds of molasses every day. The total molasses for the season will be 45,360 maunds (assuming a season 120 days duration). Calculating on the worst quality of molasses containing 42·5 per cent. total sugars, the theoretical yield of Acetic Acid will be 1,058,219 lb. or say, 10 lakhs pounds of Acetic Acid. The current price of Acetic Acid being about 5*d*. per lb. (or annas 4 per lb.) the cost of Acetic Acid produced will be about 2½ lakhs of rupees. The practical yield of Acetic Acid will be approximately 2/3rd of this so that the gross income will be Rs.1,66,670 per year.

It may be pointed out that the manufacture of vinegar from black-strap molasses for edible purposes has many technical difficulties. Besides, vinegar for edible purposes has a very limited sale in India at the present time. The real solution lies in the manufacture of Glacial Acetic Acid, which will be starting point for the manufacture of various allied products enumerated above, which have to be imported at present.

Experimental work on this phase of the utilization of molasses is in progress in the Sugar Research Laboratory at Cawnpore, and may lead to the development of a new industry in India.

The manufacture of alcohol from molasses

A great many owners of sugar factories do not realize the great advantages and profits that could be derived from a distillery connected with their factory. Up to the present time many of them have considered the molasses as a waste product of little or no value, and if they cannot sell it at any price they will dump it into the river or burn it. In such cases they either get into difficulties with the local authorities on account of the contamination of the water and the bad odours resulting therefrom, or else they get boiler tubes all covered with dirt without obtaining in the end any practical increase in motive power. However, it is easy to see that alcohol may yield almost as important profits as those derived from sugar, and in certain cases even larger ones.

(*i*) *Advantages of distilling the molasses at the sugar factory*—In addition to the profits to be derived, a distillery connected with a sugar factory would have other important advantages. This distillery would enable the planter to make quite a little of profit out of the spoiled sugar products from his factory (over-heated sugar, juice and

syrup in fermentation, sugar sweepings, etc.). It happens some times, in fields only recently put under cultivation, that the cane has such a rank growth that its juice is very impure and is absolutely worthless for making sugar crystals. This juice could also be sent to distillery, where it could be used with profit instead of reducing the average yield of the sugar factory. Furthermore in those places where fuel is high, it would be advisable to work up in the distillery all low grade products (string molasses) instead of trying to crystallize them at the expense of fuel and only obtaining a small quantity of low grade sugar. It would often be more economic and more profitable to use a part of the maceration juice of the last mill for dissolving the molasses to be fermented instead of sending them back to the factory, where they reduce the purity of the juice, make it difficult to produce first class sugars, and increase considerably the quantity of water to be evaporated. Summing up, one may say that from the standpoint if increased profits as well as of easier operation, it is evident that it would be very advisable for the planter to have his own distillery and safeguard his future from molasses buyers. Many sugar manufacturers believe that the manufacture of alcohol is very costly, difficult, and that it makes the work of the factory very complicated. As a matter of fact, things are entirely different, and very often the distillery facilitates the economical operation of the business. Those factories which have sufficient tank space to store the molasses, produced during the campaign, can ferment them during the off season thus assuring work for the best labourers in their sugar factory, instead of laying them off. While those factories which are not provided with enough tank space can ferment a part of their molasses during the grinding season instead of having to run them into the river or to stop the factory.

(ii) Process of manufacturing alcohol from molasses—The manufacture of alcohol is neither difficult nor complicated in itself. By using modern fermentation methods the work is almost automatic and the result certain. It may briefly be described as follows:

The molasses is pumped from the supply tanks to the processing tanks, diluted with an equal volume of water and thoroughly mixed. The dilution at this point is not standard and may vary in different distilleries. It is here sterlized or otherwise treated to prepare it for the Yeast fermentation. The processed molasses is then run into the fermenting tanks where it is further diluted with water. The final dilution gives a mixture which corresponds approximately to 1 part by volume of the original material to 4, 5, or 6 volumes of water. Yeast is then added and the fermentation takes place, the temperature of the mixture rising from the initial temperature of about 80°F. to a final temperature of 100°—105°F. unless means are provided for controlling the temperature in such manner that it remains near 90°F. throughout the process. When fermentation is complete, the

beer, as it is termed, ordinarily contains from 6 to 8 per cent. of alcohol. Usually the alcohol in the beer is separated by a primary distillation. The resulting product still contains too large a proportion of aldehydes, water, and higher boiling components (fusel oil) to be used commercially, so it then undergoes a second distillation or rectification. Modern apparatus for distillation is of the continuous type and is quite complex and elaborate. The by-products obtainable are carbondioxide, fusel oil and distillery slops, the latter being available for the production of a fertilizer material by drying.

When we study the manufacture of alcohol a little more closely we readily see that this industry has advanced much more, where alcohol from cereals and grains is concerned than where molasses and cane juices are employed as raw materials. This is due to several reasons, technical as well as economic: Distilleries of grain alcohol are located in the temperate zone, in important industrial centres, where it is easy to find up-to-date machinery at reasonable prices and a better class of labour. The raw material (grain) is completely sterlized during the boiling which precedes saccharification, and since it contains only substances which are favourable for the development of yeast, the fermentation proceeds perfectly undisturbed and gives the maximum yield of alcohol. Cane molasses, on the other hand, are usually in a more or less advanced stage of decomposition and contain an enormous quantity of bacteria and wild yeasts. The mineral salts of the cane and the chemicals used in the process of manufacture of sugar have accumulated in these molasses, making the work of the yeast still more difficult. Furthermore the hot climate of the tropics being very favourable for the development of bacteria and wild yeasts is inimical to good fermentation. Sterlization of the wort before fermenting is out of the question, because the fuel as well as the water necessary for cooling the wort afterwards are too expensive.

(*iii*) *Importance of proper fermentation*—Many manufacturers of alcohol do not have a clear idea of the important part that fermentation plays in their distillery. Quite frequently one finds factories, which are equipped with magnificent modern stills of the continuous type in which, furthermore, all the machinery is of the highest type and in perfect order, and which nevertheless leave the fermentation room in the care of a foreman, who has absolutely no technical knowledge of the fermentation process. These people do not understand that the splendid still does not produce the alcohol, but only extracts with more or less success that which is produced by the yeast during fermentation. Such manufacturers would obtain much better results with a well constructed ordinary still, but with much better care in the fermentation room. It is the yeast which produces alcohol while the still only recovers it. With an inferior still they might lose a maximum of 10 per cent. of the alcohol in the beer, while an inferior yeast will

fail to produce 40 to 50 per cent. of the total alcohol that should be obtained from the wort. For this reason the distiller should always pay particular attention to his fermentation room. When fermentation once goes on satisfactorily, he can then use his additional profits obtained for installing any improvements in his still that seem desirable, in order to recover all his product, well rectified, and without any losses.

(*iv*) Yield of alcohol from molasses dependent on the yeasting process employed.

While well equipped factories producing alcohol from grain come very close to the theoretical yield (which is 7·31 gallons of absolute alcohol for every 100 lb. of fermentable sugars), we might say that the yield of distilleries using molasses as raw material is as follows:

(1) In distilleries which use only the yeast occurring naturally in the material (wild yeast) 40 to 60 per cent. of the theoretical yield, i.e. from 2·9 to 4·4 gallons of absolute alcohol from every 100 lb. of fermentable sugars.

(2) In distilleries using compressed yeast from 50 to 75 per cent. of the theoretical yield, i.e. from 3·6 to 5·5 gallons of absolute absolute alcohol for every 100 lb. of fermentable sugars.

(3) In distilleries using antiseptic agents from 70 to 85 per cent. of the theoretical yield i.e. from 5·1 to 6·2 gallons of absolute alcohol for every 100 lb. of fermentable sugars.

(4) In distilleries working with pure yeast apparatus from 85 to 95 per cent. of the theoretical yield, i.e. from 6·2 to 6·9 gallons of absolute alcohol from every 100 lb. of fermentable sugars.

On the basis of molasses of normal composition, i.e. containing 55 per cent. of total fermentable sugars this would correspond to the following yields:

1. *Natural Yeast*—3·5 to 5·4 gallons of molasses for each gallon of absolute alcohol produced.

2. *Compressed Yeast*—2·8 to 4·2 gallons of molasses for each gallon of absolute alcohol produced.

3. *Use of Antiseptics*—2·5 to 3 gallons of molasses for each gallon of absolute alcohol produced.

4. *Pure Yeast*—2·2 to 2·5 gallons of molasses for each gallon of absolute alcohol produced.

It will be seen from what has been said above that only the work with the antiseptics gives an yield anywhere near that produced by pure yeast. But this system has the great drawback that it requires very expensive chemicals, which increase the cost of producing the alcohol.

Fermentation with Pure Yeast

The investigations of Pasteur have demonstrated that the alcoholic fermentation of saccharine liquids is due entirely to a special micro-organism "Yeast". He also showed that the diseases of wine, beer, and all fermented liquids in general, as well as poor fermentation, were caused by the development, in these same liquids, side by side with yeast of other micro-organisms or microbes, which produce substances detrimental to the yeast itself such as acetic acid, butyric acid, etc.

Confining ourselves entirely to the question of industrial fermentation, we may say that the losses of alcohol, which are caused in the cases of incomplete fermentation by these microbes or wild ferments, may be classed under two heads :

(*a*) The microbes consume for their own development a large part of the fermentable sugar and produce substances which are either immaterial or else positively harmful from the standpoint of the distiller.

(*b*) A large part of these substances (specially the butyric acid) is very detrimental to the yeast as it reduces its fermenting power with the result that a part of the sugar remains unfermented. In short there is a reduction in the alcohol yield, because a part of the sugar is converted into acids and esters, and because the yeast is prevented from completing the transformation of the remaining sugar into alcohol. This gave rise to the idea of using only pure yeast in industrial fermentation, i.e., such yeasts that are entirely free from contamination with these harmful ferments.

It is clearly seen therefore that the use of pure yeast will make it possible to avoid the sugar losses mentioned above and to make sure in this way of the highest possible alcohol yield. At the same time, since the fermented wort is free from the impurities produced by those microbes, the alcohol obtained will be of finer quality, better flavour, and the distiller will in the process of rectification have less waste and a smaller proportion of low grade products. Moreover it will be possible to select special strains of yeast to suit the raw material employed, to suit local temperature conditions, water used, etc., and also to make the quality of alcohol which one wishes to produce.

Methods of using Pure Yeast

There are at present in vogue two practical methods of using pure yeast in the distillery :

1. The first and older method consists in using a pure yeast culture for preparing the first seeding. On the following day the yeast is reproduced, either by cutting a vat in active fermentation to seed another, or by keeping a part of the first bottom to start a new one. This method can be used with good results only in small establishments and

has the disadvantage that the yeast becomes quickly contaminated and soon loses its quality.

2. In the second method, a special apparatus is used, which produces every day the necessary quantity of yeast for the complete fermentation of all the wort in a perfect manner. This system has the advantage that the yeast retains its purity and therefore always gives the maximum yield.

In this way one completely avoids those mishaps in fermentation which occur from time to time with other methods of working, even in the best managed factories. The large factories, which want to employ pure yeast, must use the second method because, as shown above, they will have to multiply the first pure yeast culture so much before using it that it is likely to lose all its purity and at the same time all its efficiency.

Acclimatization of Pure Yeast

It has been the experience of expert distillers that it is not possible to get the same fermentation efficiencies in the distilleries of the tropics as are achieved in those situated in the colder climates, although the same strains of yeast and the same raw materials are used at both places. It has been proved that this is due to what is called "High temperature high alcohol complex", which is very commonly obtained in distillery practice under tropical climates and adversely attacks the activity of the yeast.

For instance it is not always enough to have a constant supply of pure yeast of a particular strain, but certain other conditions are requisite for the purpose of harnessing the yeast to do a particular kind of work as required in the distillery. Thus it may be necessary to make yeast ferment washes at a comparatively high concentration and at high temperatures as usually prevail in the tropics.

It is well known that under ordinary conditions it is not possible to carry on the alcoholic fermentation beyond 1056-60 gravity of the wash. The yeast becomes usually inactive if alcohol percentage also becomes too high in the wash. The yeast, however, can be made to do its work efficiently if acclimatized by stages to the above unfavourable environments.

Similarly a particular stain of yeast has a known optimum temperature at which it can do its maximum work. The range of optimum temperature of different strains of yeast varies from 35° to 55°C. beyond which its activity slackens down considerably. In the tropics, where very high temperatures prevail in certain seasons of the year, it is evident that there is every possibility of the yeast activity diminishing to a considerable extent.

A combination of both these properties of yeast is obtained in the phenomenon of "High temperature high alcohol complex", so that a pure yeast loses its activity when certain concentrations of alcohol are

produced in the beer and this stage is likewise controlled by the temperature... Thus the higher the temperature attained during fermentation the lower will be the alcoholic concentration at which the yeast will become inactive, in spite of the presence of surplus saccharine contents in the fermenting liquid.

The writer has recently worked a process in the laboratories of Dr. William L. Owen of Baton Rouge, Louisiana, by which pure yeast can be acclimatized to carry on the fermentation efficiently under the unfavourable environments of high temperature high alcohol complex. The importance of such a process can be realized by the fact that it will bring about a considerable economy in steam consumption in the rectification and distillation processes, as it will be possible to ferment washes of higher densities resulting in higher alcoholic content of the beer and a comparatively smaller volume to be handled. The process has yet to be tried on a large scale.

Acidification of the Worst

The next important stage in the manufacture of alcohol is the acidification of the wort. It may be conservatively stated that it ranks only second to the process of yeasting in its effect upon the efficiency of alcohol manufacture from molasses. If unintelligently employed, it may render entirely ineffectual the utilization of the most efficient strains of yeast. On the other hand, the intelligent and discriminating use of acid may greatly increase the efficiency of the poorest strains of yeast, and may even direct the spontaneous fermentation of molasses into fairly productive channels. In spite of its great importance, however, the control of acidification in molasses distilleries has not yet become a standardized procedure. At the present time the general practice is to add a constant amount of acid to all types of molasses, irrespective of source or composition. It is not surprising, therefore, that unsatisfactory and unprofitable yields of alcohol frequently result from the improper acidification of the wort. Molasses with unusually large acid requirements is very susceptible to trouble from bacterial infection, when diluted and set up in the customary way. Apparently, the accurate and rational method of determining the acid requirement of molasses for distillery purpose would be by measuring the H-ion concentration.

After extensive study of this problem in the laboratory and on commercial scale it has been found that the optimum condition of the wort for efficient fermentation is attained at pH5 for most of the molasses and the average type of yeasts in use for the manufacture of alcohol, but the real criterion for a wort, optimum with respect to H-ion concentration, is that there is no tendency for the solution to show a lower pH. value at the end than at the beginning of the fermentation. If enough care is taken about the acid requirements of molasses in the distillery practice there is no doubt that it will lead to much better fermentation efficiencies.

Distillation and Rectification

The alcohol in the fermented wash is separated, concentrated and purified by distillation. There are two methods commonly employed. By the first and the least efficient method the fermented wash is run into a continuous still, which separates the alcohol at a strength of 50 to 70 per cent. by volume. This alcohol is impure, containing all the fermentation products. The residue known as "Slop" is discharged continuously and free from alcohol at the base of the still. The alcohol thus obtained from the separating still is accumulated in tanks, and redistilled in batches in a rectifying still of the non-continuous type. This second distillation completes the concentration to 95-96 per cent. and permits the separation of the impurities from the alcohol.

By the other and more efficient method, the entire concentration and rectification of the fermented wash is accomplished in a multiple column continuous still. This method has the advantage of considerable economy of steam and water, the elimination of intermediate products, and automatic control of operation, resulting in the production of uniform grades of products. The fermented wash is continuously fed into the still after being preheated by the waste heat of the slops. The purified alcohol—at any desired strength up to 95-96 per cent. by volume —is drawn off from the upper plates of the column, while the residual slop is discharged continuously and free from alcohol at the base of the still.

The impurities of the alcohol may be classed as (1) "Head Products", which are more volatile than alcohol and (2) "Fusel Oils" which are less volatile than alcohol. In continuous distillation, these impurities are separated by taking advantage of the difference in boiling points between the Head Products, purified alcohol, and fusel oils. The "Heads" alcohol is distilled through the final condenser; the purified alcohol is drawn off from the upper plates of the rectifying column; while the fusel oils are drawn off from the column at the point of their maximum concentration.

The strength, purity and uniformity of the alcohol produced will depend upon the design and efficiency of the still. The amount of steam and cooling water required per gallon of alcohol and the ease of operation and control also are greatly influenced by the character of the distilling equipment. In most of the modern continuous type stills provision is made for the maximum utilization of waste heat of vapours and slop so as to permit the utmost economy of steam. Condensation surfaces are amply proportioned to save cooling water. Automatic control of feed, steam, slop discharge and cooling water result in uniform operation. Convenient feed and product gauges and testers, together with the positive automatic controls, permit the operation of the still with ease and economy.

Cost of producing 95 per cent. alcohol

The cost of production of alcohol depends upon the location of the manufacturing plant, kind of raw material, price paid for raw material,

and the scale of production. It is estimated that under the present conditions the plant operating cost of producing one gallon of 95 per cent. alcohol from blackstrap molasses in the United States is about 6 cents per gallon, exclusive of the price paid for molasses, when the unit is operating at the highest efficiency and producing 30,000 gallons of alcohol per day. With molasses at 5 cents per gallon (some contracts have recently been made for molasses at 2 to 3 cents per gallon) and with a yield of 1 gallon of 95 per cent. alcohol from 2½ gallons of molasses, the cost of production of 95 per cent. alcohol will be 18½ cents per gallon equivalent to annas 9 per gallon.

The cost of production in India will in no way be more than that in the United States on account of the fact that, although the fuel may be somewhat dearer, the cost of labour is much cheaper. Besides this fact, the molasses in the United States have to be imported, while in India they are a waste product of a home industry.

The following is an estimate of calculated cost of production of 1 gallon of 95 per cent. alcohol on a plant unit of 8,000 gallons capacity per day under Indian conditions :

Basis—One day's operation.

8,000 gallons of 95 per cent. alcohol per day.

20,000 gallons per day of molasses containing 50 per cent. sugars, equivalent to 3,800 mds. of molasses.

Materials and Utilities

	Amount per day. Rs. a.
Sulphuric acid 200 lb. at 1 anna per lb.	12 8
Ammonium sulphate 80 lb. at Rs. 4-8 per md... ..	4 8
Steam 280,000 lb. requiring 33 tons of coal of 7,000 B.T.U. at Rs. 15 per ton	495 0
Water 80,000 gallons for fermenting at 2 annas per thousand gallons	10 0
Water 650,000 gallons for cooling, steam and other requirements	81 4
Total ..	603 4
Total cost of materials and utilities	603 4 per day.
Cost per gallon of 95 per cent. alcohol =Rs.603-4 0 / 8,000 0	=14·5 pies.

Labour and Supervision

	Rs.
One Superintendent at Rs.600 per mensem	20 per day.
Two Foremen at Rs. 300 per mensem each	20 ,,
Six operators at Rs.45 per mensem each	9 ,,
Six helpers at Rs. 30 per mensem each	6 ,,
Six fillers, shippers, etc. at Rs.15 per mensem each ..	3 ,,
Total cost of labour and supervision	58 per day.
Cost per gallon of 95 per cent. alcohol .. =Rs.58 / 8,000	=1·5 pies.

Indirect Expenses—Basis 350 days working in the year assuming a total investment of Rs.10 lakhs in Machinery and Building.

	Rs. per day.
Depreciation at 10 per cent. on Rs.10 lakhs	286 ,,
Interest and Insurance on Rs.10 lakhs at 10 per cent. ..	283 ,,
Maintenance of plant and buildings	100 ,,
Total, Indirect expenses ..	672 per day

Cost per gallon of 95 per cent. alcohol $= \frac{\text{Rs.}672}{8{,}000}$ 16.1 pies.

Cost of Molasses

Assuming the cost of molasses at annas 6 per maund delivered at the distillery and on the basis that a maund of molasses produces 2 gallons of absolute alcohol, there would be required for the daily production of 8,000 gallons of 95 per cent. alcohol a total of 3,800 maunds of molasses per day costing Rs.1,425. Therefore the cost of molasses required for the production of 1 gallon of 95 per cent. alcohol would be Rs.1,425/8,000 or 25·2 pies.

Summary of cost of production of 1 gallon 95 per cent. alcohol—

Materials and utilities exclusive of molasses	14·5 pies
Labour and supervision	1·5 ,,
Indirect expenses	16·1 ,,
Cost of molasses	25·2 ,,
Total ..	57·3 ,,

Under the present conditions of excise regulations in India, it is necessary to pay an Excise duty of 5 per cent. of the cost of production and to denature the alcohol before it is shipped out from the distillery so that the following additions have to be made to the cost of production stated above :

Excise duty of 5 per cent. on 57.3 pies, say	3 pies per gallon.
Cost of denaturing with ½ per cent. pyridine at Rs.7 per gallon plus ½ per cent. of caoutchoucine at Rs.5 per gallon	10 ,, ,,
Total ..	13 ,, ,,

Therefore the total cost of producing 1 gallon of 95 per cent. completely denatured spirit after paying the Excise duty would be 70·3 pies or slightly below annas 6 per gallon under the existing Excise regulations.

A close examination of the above cost of production will make it clear that every item of expenditure has been lavishly calculated, especially the items under Indirect Expenses. The cost of plant and buildings has been estimated at 10 lakhs of rupees on the basis of a quotation from Messrs. The Lummus Company of New York, who recently installed a plant of

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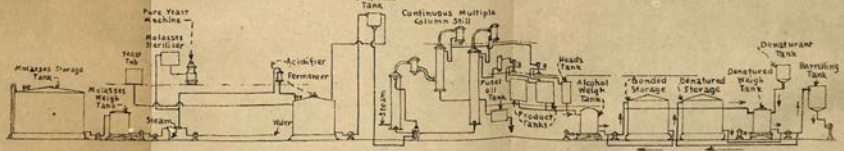
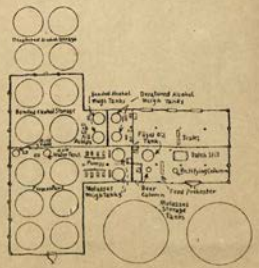
Arrangement of equipment in a modern plant for the production of ethyl alcohol by the fermentation of black strap molasses



Ground plan of the industrial alcohol plant.



the most modern type at Everett, Mass., for producing 8,000 gallons of 95 per cent. alcohol per day. The details of their quotation are as follows :

Machinery and Equipment Fas New York	$220,000
Freight at 10 per cent. of the cost	$22,000
Buildings and erection	$30,000
Storage	$130,000
Total Cost without duty ..	$402,000

It is a known fact that the prices of most of the American machinery works out more costly in India in comparison to European machinery. Besides this, considerable economies could be made in the provision for buildings, erection and storage, as given in the above quotation. If the plant is started in conjunction with a sugar factory, the initial investment would be much less. It will be seen, therefore, that the amount of Rs.10 lakhs, calculated as initial investment is decidedly on the higher side. If the amount of initial investment were reduced, the cost of production under Indirect Expenses would also be reduced correspondingly and the alcohol could be produced cheaper than the above calculated figure of annas 6 per gallon.

The ground plan and arrangement of the Everett Plant, above referred to, for producing 8,000 gallons of 95 per cent. alcohol per day is shown in the figure.

Returns from the Distillery producing 8,000 *gallons of* 95 *per cent. alcohol (denatured spirit) per day on the basis of working for* 350 *days per year.*

Assuming the selling price of annas 8 per gallon of denatured spirit.
Deduct producing cost at annas 6 per gallon.
Profit remaining for the Distiller = annas 2 per gallon.

Therefore, an 8,000 gallon plant will show a daily gross profit of Rs.1,000 per day or Rs.3,50,000 per year = 35 per cent. on the capital outlay.

No credit is made in this return for the by-products obtainable from the distillery on account of the fact that there is, at present, no market for them in India. A possible use could, however, be developed of Fusel oil for denaturing the alcohol produced from the plant. If the Excise departments could agree to this use of Fusel oil for denaturing purposes, the producing cost of 95 per cent. denatured alcohol will be materially reduced, as the cost of denaturants used at present in India represents about 18 per cent. of the total cost of producing 95 per cent. spirit, which is indeed a very high figure. I feel it is high time that the Excise Department should revise its regulations after a thorough consideration of the idea that the use of alcohol in this country for industrial purposes has to be increased, and every encouragement and facility should be given to those industries which have to use alcohol in their processes of manufacture or as a raw material.

The use of such denaturants as can be manufactured in India from sugar industry by-products, such as crotonaldehyde, Fusel oil, etc., should be developed in order to enable denatured spirit to be available at comparatively lower prices for general utility purposes.

The writer has selected a unit of 8,000 gallons capacity for calculations of production cost on account of the fact that a plant of this capacity appears to him as most feasible under Indian conditions. It is neither too big nor too small. It will require about 50,000 tons of molasses for working all the year round. It can be most profitably installed by a group of sugar factory owners on a co-operative basis in the eastern part of United Provinces, say near Gorakhpur, where most of the sugar factories are located, so that the supply of the raw material can be assured for the whole year at minimum transit costs, resulting in better profits to the sugar factory owners under molasses account.

Uses of alcohol

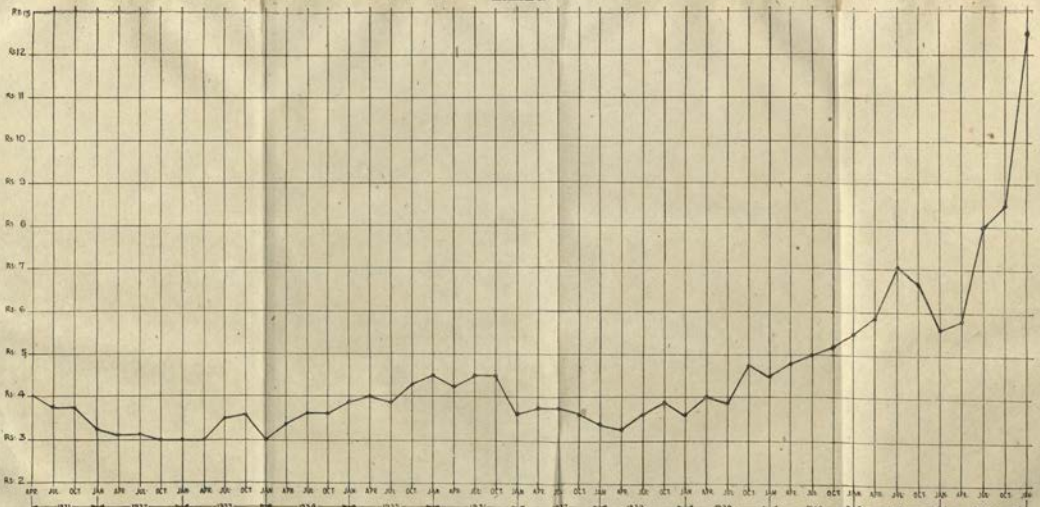
A chart is given below showing the various uses to which Ethyl Alcohol is put for industrial or public utility purposes. It is divided into five main groups, viz., Fuel, Solvent, General Utility, Raw material in Chemical Processes, and Miscellaneous. It will be clear from the chart that ethyl alcohol is a substance of very wide utility and ranks only next to water for industrial or public utility purposes. Some of the uses which could be immediately developed in India to solve the present molasses problem are: Power, heating, burning, acetic acid, and also tinctures, soap, perfumery, paints and varnishes, anaesthetics and various other chemicals.

One of the most important and significant of recent chemical developments is the great increase in the use of industrial alcohol and alcohol-products in manufacture. The U. S. Industrial Chemical Co., Inc, using alcohol as a raw material, is producing a group of chemicals which serve a wide range of important industries. First and foremost of these are the various solvents without which the present technique of production of finishing materials would be sadly handicapped. This refers to the modern nitro-cellulose lacquers—which would hardly be possible without alcohol solvents.

Again until a few years ago, Absolute (water-free) alcohol was almost a chemical curiosity. Now it is available in tank-car quantities and enters largely into lacquer manufacture.

Two other most important chemicals derived from alcohol are Ether and Ethylene gas. In their purified forms, both are indispensable anaesthetics and as such have contributed largely to the safety, comfort and progress of modern surgery.

In the manufacture of alcohol by modern methods, many industrial wastes have been eliminated and now appear as saleable by-products.



WHOLESALE PRICE OF COARSE RICE AT CALCUTTA, FROM APRIL 1931 TO JANUARY 1943.

e.g., valuable materials notably vegetable potash and ammonia, are obtained from molasses "slop", formerly thrown away, and from combustion gases, heretofore regarded merely as smoke. The recovery of the carbon-dioxide from the fermenting vats has established the dry ice and other industries utilizing carbon-dioxide. The following is a list of some of the important chemicals manufactured at present in some of the foreign countries :

Amyl Acetate, Amyl Alcohol, Amyl phthalate, Butyl acetate, Butyl phthalate, Carbon-dioxide, Ether absolute, Ethyl acetate, Ethyl chlorocarbonate, Ethyl lactate, Ethyl oxalate, Ethyl phthalate, Ethylene, Isobutyl alcohol, Normal propylalcohol, Vegetable potash, Refined Fusel oil, Vinegar, and Absolute alcohol—pure and denatured.

Necessity of research work in the Sugar Research Laboratory pertaining to utilization of the by-products of the sugar industry.

Enough emphasis has been laid in the different sections of this report with regard to the necessity of research work for the efficient utilization of the by-products of the sugar industry under Indian conditions. A list is given below summarising the various phases on which research work could be carried on at the Sugar Research Laboratory in the best interests of the Indian Sugar Industry under the existing conditions :

Cane Trash

1. Activated composts from cane trash.
2. The value of cane trash (particularly tops) as a food for cattle.

Press Mud

1. The best method of utilizing the press mud as a manure for Indian soils : (*a*) Burning, (*b*) Composting, (*c*) Direct application to land in the form of powder or slurry.

Bagasse

1. Alpha-Cellulose from Bagasse.
2. Paper from bagasse.
3. Fibre Board from bagasse.
4. Activated compost from Bagasse.
5. Utilization of the Ash obtained by burning bagasse.
6. As a Feed-stuff for cattle.

Molasses

1. Recovery of cane sugar from molasses.
2. Cattle feeds from molasses.
3. Molasses as a source of various organic and inorganic chemicals.
4. Possibility of manufacturing Glucose from molasses.
5. Improved methods of fermentation of molasses.
6. Investigations pertaining to new uses of anhydrous and rectified spirits.

7. Manufacture of Vinegar and Acetic Acid on a semi-large scale.
8. Resinification of molasses by condensation with aldehydes.
9. Possibility of using alcohol as a Carburant.

It seems desirable that a small experimental distillery and an Acetic Acid plant be installed by the side of the present experimental sugar factory, where research pertaining to this phase of the sugar industry could be efficiently carried on semi-commercial lines. A small feed-plant would also be a valuable asset to the existing sugar factory, where feeds of different types could be prepared in sufficiently large quantities to enable their being tried on the animals for a prolonged period in order to assess their true value. With these additions made, the existing sugar factory will become a model to which the pioneers of the sugar industry in India will look for guidance and assistance in their various technical difficulties.

Part II

Power alcohol

CHAPTER I

Power Alcohol

Historical—Scientists of eminence had long considered the idea of using alcohol as a fuel for the generation of power, and had predicted that the future liquid fuel requirements of the world, when the petroleum resources are exhausted, will have to be met with alcohol. The results of experiments conducted by them at that time with 95 per cent. alcohol showed that in order to be economical, this fuel would require specially designed engines, which could not be run on gasoline. It was after the signing of the armistice and with the immediate necessity of disposing of very large quantities of alcohol (95 per cent.) accumulated during the hostilities that the suggestion was made of using it as a fuel in admixture with other fuels and specially with gasoline.

The decision then made by the French Ordnance Department to utilize 1,500,000 hectolitres of 95 per cent. alcohol for power purposes soon revealed serious difficulties, as it was not possible to burn pure alcohol in engines, designed to run on petrol, economically. At the same time it was found that mixture of 95 per cent. alcohol and petrol do not remain homogeneous, but separate into two layers of different compositions.

The scientists of different countries, particularly of Germany, Sweden and Poland, took up the study of this subject in their laboratories and found out various homogenisers, which, when added to a mixture of petrol and 95 per cent. alcohol, could make the mixture stable. Quite a large amount of this type of work was done on small commercial lines in Natal, Brazil, Argentine, and Hawaii with the idea of utilizing the waste product (molasses) of their sugar industry and minimising the imports of petroleum. This work resulted in the installation of few plants in the tropics for the production of Alcohol-Ether Fuel, which has subsequently been completely replaced by the better absolute alcohol-petrol mixtures.

The results of investigations in different countries led to the conclusion that if alcohol was to be used for Power purposes in internal combustion engines it must be made anhydrous, absolute alcohol being miscible with gasoline in all proportions. The problem then became of making 95 per cent. alcohol anhydrous, which was subsequently solved by the development of the Azeotropic processes for the continuous production of absolute alcohol.

At that time appeared in France the "National Fuel"—a mixture of 50 per cent. petrol and 50 per cent absolute alcohol. This mixed fuel

did not meet with much appreciation, as it could only be used for trucks, and was too strong to be advantageous in the usual type of engines and required a special adjustment of the carburetter. It was later discovered that this difficulty was due to there being too high a percentage of absolute alcohol in the mixture, which was purposely kept very high to eliminate all risks of decantation.

Further investigations established the superiority of mixtures containing 70 to 80 per cent. standard gasoline and 30 to 20 per cent. absolute alcohol. The advantages of these mixtures were such that they became popular on their own merits so much that since 1928, i.e., before any legal application Germany had already used about 26,500,000 gallons of "Monopolin" fuel containing 20 per cent. absolute alcohol per annum. In Sweden, where no legislation exists to this effect, the "Lattbentyl" (75 per cent. petrol and 25 per cent. absolute alcohol) is being exclusively used. It has not only completely replaced the "ESSO" super fuel but the users are willing to pay 1 or 2 ores more per gallon than for pure petrol. In Australia a fuel "Shellkol", containing 15 per cent. absolute alcohol enjoys similar success.

In many foreign countries alcohol is now used in a motor-fuel blend or mixture. Several factors have contributed to the development of the use of alcohol in these foreign countries. In some European countries the objective is to provide additional outlet for potatoes, in some it is molasses or beet roots, and in others fruits. The use of alcohol is also supported by nationalistic arguments as to the need of being more independent of the foreign supplies of petrol. In most cases the countries have surplus agricultural products but must import petroleum or gasoline. The appeal for alcohol is the appeal for using the home products. Furthermore, the need for restricting purchases of foreign exchange in certain cases is a factor of some importance. Practically in all cases the price of petroleum or gasoline is high and the high prices tend to encourage the substitution or use of alcohol in blends. In Sweden, for example, alcohol can be produced as a by-product of the woodpulp industry at a low cost. In all countries, however, with the possible exception of Sweden, aid to agriculture has been a factor in requiring or encouraging the use of alcohol in motor fuel.

Retail prices per gallon of gasoline, including tax, in specified foreign markets, December, 1932

	Cents.
Stockholm	19·1
Vienna	28·6
Lyons	28·9
Berlin	33·3
Rome	22·7

Approximate use of alcohol for motor fuel and consumption of alcohol blends, other blends and straight gasoline, 1930

Country	Alcohol used in blends	Consumption of motor fuel		
		Blends containing alcohol	Other blends	Straight gasoline
	Barrels	Barrels	Barrels	Barrels
Australia	5,700	34,000	49,400	6,364,100
Brazil (2)	(3)	(3)	..	1,822,000
China	3,600	6,500	..	(4)711,400
Czechoslovakia ..	34,000	68,000	120,000	1,475,000
France	168,000	336,000	1,584,000	15,450,800
Germany	425,000	1,700,000	..	(4)13,412,000
Hungary	70,000	375,000	..	209,400
Philippines	101,100	(5)	..	(6)646,700
South Africa	(7)	(7)	..	(6)1,867,000
Sweden	48,000	192,000	..	2,635,000

NOTE :

(2) 1931.

(3) Sales were part of motor fuel supply in 3 cities.

(4) Includes some gallons used in other blends.

(5) Not available.

(6) Includes gasoline used in alcohol blends.

(7) Sale largely confined to one city.

Among the more important countries that have experimented with alcohol in motor fuel are France and Germany. In Germany the primary purpose is to make a better market for potatoes. Although the cost of gasoline in Germany is relatively high, the use of alcohol from potatoes increases the cost of the motor fuel. This seems to be the greatest complaint made of its use.

The cost of gasoline delivered at Hamburg is 5·5 cents per gallon, and the tariff adds 15 cents per gallon. The Government monopoly pays the farmers 29 cents per bushel for potatoes, and the cost of producing alcohol from these potatoes is estimated at from 23 to 28 cents per gallon. The monopoly sells the alcohol (99 per cent.) to oil companies at 46 cents per gallon. The retail price of gasoline in Berlin is reported to be 34 cents per gallon and the alcohol-gasoline blend is retailed at the same price. The gasoline-alcohol-benzol blend sold at a premium of 4 cents over the straight gasoline and the alcohol-gasoline blend. The Government do not require all the motor fuel to include alcohol. The importers and producers of motor fuel are required to take from the monopoly alcohol equivalent to 10 per cent. of their imports or production. About 50 per cent. of the motor fuel sold is straight gasoline, 10 per cent. is a gasoline-alcohol blend, and 40 per cent. a gasoline-alcohol-benzol blend.

In France also, a considerable quantity of alcohol is used in mixture with petroleum. In that country molasses, beet roots and fruits furnish the alcohol. In France, as in Germany, the alcohol costs more than gasoline. The French Government pay about 38 cents a gallon for alcohol and in turn sells it to oil companies for 17 cents per gallon, which is approximately the cost of gasoline. The Government makes up this loss by means of a tax on all gasoline and kerosene, while the blended fuel is now exempt from this tax.

The use of alcohol in gasoline was not required in Czechoslovakia. A special fuel "Dynalkol" has been in use since 1922. The composition of this fuel is 30 per cent. gasoline, 20 per cent. benzol and 50 per cent. alcohol. A law has been drafted making the mixture of 20 per cent. alcohol and 80 per cent. gasoline compulsory. In Czechoslovakia the use of alcohol increases the cost of motor fuel by about 12 cents.

Sweden, as pointed out before, uses an alcohol-gasoline blend without any compulsion. The alcohol is obtained from the cellulose residues of pulp factories. The first trial began in 1911. The War gave impetus to its use. It is reported that the use of the blend of mixture involves no change in the operation of the engine. It increases the power and smoothness of the engine without increasing the amount of fuel used. Furthermore, in spite of the low temperature in Sweden during a very considerable part of the year, the mixture remains homogenous and causes no difficulty in starting.

The names and contents of some of the mixtures that have been used in foreign countries are as follows :

Composition of foreign alcohol motor fuel blends

Country	Trade name	Contents					
		Alcohol	Gasoline	Ethyl-ether	Benzol	Kerosene	Total
		%	%	%	%	%	
Australia ..	Shellkol ..	15—35	65—85	..	..	..	100
Brazil ..	..	70—90	..	10—30	..	..	100
Do. ..	Gasalco ..	88	12	..	..	..	100
China ..	Benzolite ..	55	..	..	40	5	100
Czechoslovakia	Dynalkol ..	50	30	..	20	..	100
France ..	Carburant National.	50	50	..	..	..	100
Germany ..	Monopolin ..	25	75	..	..	..	100
Do. ..	Aral ..	20	60	..	20	..	100
Do. ..	Bevaulin ..	25	75	..	..	..	100
Hungary ..	Motalco ..	20	80	..	..	..	100
Sweden ..	Lattbentyl ..	25	75	..	..	..	100
South Africa	Natalite ..	60	..	40	..	..	100

Many countries have tried experiments that have not been notably successful. Administrative difficulties have arisen in many cases. However, as noted above, some have succeeded in developing the use of an alcohol blend or mixture upon its own merits, and others have succeeded in enforcing, directly or indirectly, the use of alcohol. Naturally, motorists and those who are interested in the automobile industry object to the imposing of any additional burdens upon motoring. The taxes on gasoline and upon automobiles are high in many foreign countries, and requirements to use alcohol in motor fuel are looked upon as another form of tax increasing a burden that already exists. It is interesting to note, however, that the International Permanent Bureau of Automobile Manufacturers, Paris, after condemning vigorously the imposition of additional burden upon motorists in foreign countries, arrived at the following conclusions :

"To sum up, one can therefore declare that from strictly technical point of view, the advantages presented by the use of a mixed fuel containing petrol and alcohol, compensate approximately the disadvantages on condition, nevertheless, that the following rules are complied with :

(1) The grade of degree of the alcohol mixture should not exceed 25 per cent.

(2) The alcohol used in the mixture must be in a rigorously anhydrous state.

(3) The distribution of the petrol fuel alcoholized at 15 per cent. has to be so made that one may be sure of obtaining it at any time throughout the whole territory, so that the user shall not be forced to constantly change the nature of the fuel which he uses."

The above is a concise summary of the results of experience in foreign countries regarding the alcohol-gasoline blend.

CHAPTER II

Discussion of Absolute Alcohol as a Carburant

Behaviour of Alcohol Gasoline Fuels—In reviewing available information on the performance of alcohol and alcohol-gasoline mixtures as fuel for internal combustion, no significant difference appears to be evident other than what might be attributed to experimental error, when burning mixtures up to 10 per cent. if absolute alcohol and regular gasoline. The heat value of gasoline is approximately 19,200 and of alcohol 11,600 British Thermal Units per lb. or 114,850 and 78,900 B.T.U. per gallon, respectively. On this basis a gallon of 10 per cent. mixture of absolute alcohol and regular gasoline contains about 97 per cent. of the heat units contained in a gallon of regular gasoline. The 3 per cent. reduction in heat units available, however, would be practically offset by the denser charge due to the cooling effect of the alcohol. The maximum power, therefore, in a given engine designed for gasoline would be about the same when using either plain gasoline or the blend. Fuel consumption increases in a given engine with the increase in the percentage of alcohol until on alcohol alone the fuel consumption becomes approximately 50 per cent. greater than on gasoline. If, however, the compression be raised, the fuel economy of alcohol could be made to approach that of gasoline.

Observations and tests made by the U. S. A. Government Experts on the behaviour of alcohol-gasoline mixtures in internal combustion engines, including trucks and tractors, indicate that absolute alcohol can be mixed with regular gasoline at room temperature in any proportions. These results agree with the findings of other Government agencies. Tests with mixtures of 10 and 20 per cent. absolute alcohol compared to that on straight gasoline, indicated very little difference in maximum horse-power developed, fuel economy, or acceleration.

It was found that the octane rating (anteknock value) of regular gasoline is improved by the addition of alcohol. When 10 per cent. absolute alcohol by volume was added, the average rating of three market samples of gasoline was increased from 66 to 74 by the addition of 30 per cent. to 85 (present ethylised gasoline rates 78).

The best available information indicates that there should be no difficulty in blending absolute alcohol with the various brands of low grade automobile gasoline. The volatility of this lower grade gasoline apparently is not such different from that of the regular gasoline but the octane rating is considerably lower (an average of 55 as compared

with about 66). The volatility and octane rating may vary somewhat in different parts of the world due, principally, to the source of crude oil from which the gasoline is obtained and to the nature of the process employed by the refineries. The addition of alcohol would greatly improve the anti-knock value of the lower grade fuel. In fact, the improvement of the octane rating by adding alcohol to the lower grade oil appears to be greater than that realized from adding the same amount to the higher grade gasoline. Iowa tests have shown that by adding 10 per cent. alcohol to a gasoline rating 56, the rating was increased to 65, whereas by adding 10 per cent. alcohol to a gasoline rating 66, the increase was to 74.

Performance Tests—Because of the wide variation in conditions due to weather, inherent features of design, personal equation, and other factors, the performance of different units is bound to vary.

In the tests on a stationary multiple-cylinder engine, the maximum horse-power and fuel economy varied slightly from 16·09 horsepower and 7·85 brake horsepower-hours per gallon respectively on straight gasoline to 16·34 horsepower and 7·77 brake horsepower-hours per gallon on 10 per cent. alcohol blend and to 16·52 horsepower and 8·05 brake horsepower-hours per gallon respectively on 30 per cent. alcohol-gasoline blend.

Road tests with trucks ranged (1) with a half ton (unloaded) from 16·67 miles per gallon on straight gasoline to 16·66 on 10 per cent. alcohol admixture and to 15·92 on 20 per cent. alcohol admixture fuel; (2) with a 1½ tons (net load 3,380 lb.) from 12·73 miles per gallon on straight gasoline to 12·68 on 10 per cent. alcohol admixture and to 12·62 on 20 per cent. alcohol fuel; (3) with a 3½ tons (net load 7,700 lb.) from 5·43 per gallon on straight gasoline to 5·79 on 10 per cent. alcohol admixture and to 5·85 on 20 per cent. alcohol fuel.

Acceleration tests of the above trucks showed that the pick-up was slightly retarded as the alcohol content of the mixture was increased.

On the tractor belt tests a 4-cylinder tractor engine delivered a maximum horsepower of 31·8 on straight gasoline and 31·6 H. P. on a 10 per cent. admixture with a fuel consumption of 6 and 6·4 brake horsepower-hours respectively per gallon.

A two-cylinder horizontal tractor engine delivered a maximum horsepower of 31·7 on straight gasoline and 32·2 horsepower on a 10 per cent. admixture of alcohol with a fuel consumption of 7·7 and 7·6 brake horsepower-hours per gallon respectively.

In all the above tests the carburettor setting was kept the same on the different units—the original position set for burning gasoline alone.

Exhaust gas analysis showed that the combustion of the mixtures was more complete than of gasoline alone. This may be due to the

fact that the ordinary carburettor setting on gasoline was richer than required for maximum economy, and that with greater air-fuel ratio existing—when the mixture was used—more complete combustion took place.

Iowa State College, Ames, Iowa, states that after experimenting with several cars, it was not found that the alcohol caused the fuel-tank or fuel-line to rust. Alcohol, in fact, cleaned out the fuel system removing dirt and gums. The filters that are installed in all cars should take care of this matter. If they do not and once the system has been cleared, there will be no further trouble from this source.

M. Paul Dumanois reports in La Revue Agricole, 1932, that a small addition of alcohol to gasoline increases the power theoretically and also practically. The maximum increase in power is reached at between 15 to 20 per cent. of alcohol, when a further increase of alcohol causes a reduction in power.

The consumption per horsepower-hour is practically the same with alcohol as with gasoline to which 10 per cent. alcohol has been added. The starting is about as easy in the one case as in the other. The ante-knocking properties are improved, the mixture is stable, and there was no separation during the time the fuel was in storage.

W. E. Cross in the Industrial and Agricultural Review (France) comes to the conclusion that the addition of alcohol to gasoline gives the following advantages:

"The explosions are less noisy, the motor heats up less, and the combustion is more complete. The consumption of the fuel and the lubricating oil per kilometer travelled are reduced in spite of the increase in power."

A communication from a prominent Oil Company states: "Although alcohol has a much lower calorific value than gasoline, the mileage and power output of an engine will be practically the same as that on straight gasoline if not more than 20 per cent. alcohol is added to the gasoline. This is partly because the alcohol has higher viscosity than gasoline and therefore if the carburettor adjustment is not changed but the same setting remains as for straight gasoline, the fuel-air ratio of an alcohol-gasoline mixture will be leaner than that commonly used for straight gasoline. Most carburettors are, however, set so as to give a rather rich mixture of gasoline and air, since this provides for easier starting than a lean mixture, so that this difficulty will not be experienced in practice.

The results of many observations and experiments in the use of alcohol-gasoline mixture in various countries may be summarised as follows:

(1) Mixing of alcohol with gasoline makes for smoother engine operation.

(2) The adding of small proportions of alcohol to gasoline improves combustion and tends to prevent carbon formation.

(3) The corrosive effects of small proportions of alcohol in mixtures with gasoline appear to be negligible.

(4) There appears to be a tendency towards harder starting when using blends, particularly in cold weather and as the percentage of alcohol is increased.

(5) Existing engines appear to be able to handle up to 10 per cent. absolute alcohol-gasoline blends with but little adjustment of the carburettor or point of ignition.

(6) The solvent effect of alcohol may cause trouble with cork-floats in carburettors and fuel-tanks. The loosening of scale and gum deposits in the fuel systems may cause some difficulty, but this may become negligible after the fuel tank is exhausted the first few times (the action may cause some trouble with diaphrams in automobile fuel pumps). It is also detrimental to automobile body finished.

(7) Alcohol improves the octane rating at the rate of from $\frac{3}{4}$th to 1 number for each per cent. of alcohol added. (By adding 10 per cent. alcohol to three regular gasolines the average rating was increased from 66 to 74; and increased the rating of low grade more than the regular gasoline.)

(8) As the percentage of alcohol in the blend is increased, the compression could be increased without detonation up to roughly 200 pounds on pure alcohol. At the optimum compression, fuel consumption of the blend would approach that of gasoline. But a pressure of 200 lb. per square inch would make starting difficult and necessitate change in ignition systems.

(9) Equal power and acceleration of alcohol-gasoline blends and gasoline appear possible in the same engine but at a higher fuel consumption with the blend as the alcohol percentage increases. Roughly speaking, the consumption of alcohol alone would be 50 per cent. greater than with gasoline alone. As the percentage of alcohol in the blend is decreased, the consumption approaches that of gasoline.

Effect of water on the stability and utility of alcohol-petrol blend—The water problems may be considered from two standpoints. First, water may be present in pipe lines, storage tanks, pumps and containers, and may, therefore, be eventually introduced into the blended fuel. Secondly, fears have been expressed that water may be taken up from air owing to the hygroscopicity of the alcohol-gasoline blend, or to the condensation of water from warm air on the colder surface of a blend

The point at which water will cause separation of the alcohol from the blend depends largely on the temperature and the concentration of the alcohol in the blend. Agreement between different investigations concerning separation temperatures is quite good when low concentrations of water are present. Thus, in 10 per cent. alcohol blends the presence of 1 per cent. of water in the alcohol has been found to cause separation at temperatures ranging from 40° to 50°F. With higher concentrations of water, agreement is not so evident, but this is in some part due to different experimental conditions. It should be emphasized that with increasing concentrations of alcohol in the blend, the separation temperature is lowered increasingly up to concentrations of 20 per cent. alcohol. Beyond this point the curve expressing such a lowering tends to flatten.

From a consideration of the rather meagre data recorded in the literature, it would therefore seem that misgivings concerning the unfavourable effect of the presence of water on the stability of alcohol-gasoline blends have been somewhat exaggerated. The employment of 99·5 per cent. alcohol and the exercise of slightly more than the usual precautions now observed in the conscientious handling of gasoline should prevent any serious difficulties.

The possibility of the separation of blended fuels into two layers due to the absorption of water from the atmosphere has caused no little concern, but the data available so far minimise the dangers from this source. These misgivings probably arise from the fact that anhydrous alcohol when exposed to humid air does take up water, particularly when a large surface is exposed. However, when mixed with gasoline, conditions are entirely different. It has been found that 15 per cent. alcohol blends are actually no more hygroscopic than gasoline itself. It has also been proved that 15 per cent. blend remains homogeneous under conditions of humidity far more rigorous than those usually encountered under everyday conditions.

The dangers arising from the condensation of the water from a warm and humid atmosphere on the surface of a cold blend are more evident than those arising from hygroscopicity. In underground storage tanks, this could not be serious, because the fairly constant temperature of the air over the fuel would reduce the breathing action to a minimum and hence little opportunity would be offered for the ingress of moisture-laden air. In surface tanks it might conceivably cause some difficulty, but experiments carried out recently at the Iowa State College indicate that such is not the case.

From a consideration of the above facts it appears that the dangers arising from the absorption of water by blends either from humid atmosphere or by actual condensation on the surface, are not as serious as have been heretofore supposed, and should present no serious

obstacle to the utilization of such blends. Blends containing small percentages of alcohol would of course be more subject to separation than those containing 10 or 20 per cent. of alcohol.

Effect on Volatility of the addition of alcohol to Gasoline—Experimental evidence indicates (Journal of the Society of Chemical Industry 45, 273-280T, 1926) that the addition of alcohol (99 per cent.) has considerable influence on the fractional distillation of gasoline. This is specially evident at the lower temperatures. The alcohol apparently forms azeotropic mixtures with certain of the gasoline fractions, and such mixtures distil at temperatures lower than the boiling points of either the alcohol or the gasoline fractions.

This, of course, is equivalent to saying that such fractions possess a higher vapour pressure and hence a greater volatility than the same fractions of gasoline itself. Twenty-two per cent. of the alcohol-gasoline blend which contained 9 per cent. of alcohol (99 per cent.) distilled under 160°F., while a temperature of 221°F., was necessary to distil the same percentage of straight gasoline. Other data indicate that the maximum increase in vapour pressure or volatility is reached when the alcoholic concentration is around 5 or 6 per cent. Such a characteristic is, of course, distinctly advantageous and should influence favourably certain motor car operations. On the other hand, the difficulty on account of vapour lock may be increased by the use of alcohol in the fuel.

It will be clear from what has been said above that there is absolutely no draw-back in the use of absolute alcohol-gasoline blends for use in motor cars of the present time; on the other hand its mixing with regular gasoline imparts such valuable qualities to the motor-fuel as are very much appreciated by the motoring public. It is on account of these qualities that the use of alcohol-gasoline blends has become so popular in many of the foreign countries in a comparatively short time.

CHAPTER III

Alcohol Production of Different Countries

The table below sums up all the information that has been officially collected from 19 different countries. An examination of this table will emphasize the following points :

In all the nineteen countries molasses is transformed into alcohol. Two countries only (France and Czechoslovakia) manufacture alcohol from beet-roots, nine countries use potatoes as raw material, and seven others amylaceous materials. Yeast manufacture is also an interesting source of alcohol. Some countries, chiefly Sweden, obtain alcohol from the treatment of cellulosic industrial by-products (sulphite liquors from the manufacture of wood pulp). Finally, the manufacture of synthetic alcohol is also developing rapidly.

In the order of importance as producing countries the different nations are as follows : France, Germany, United States of America, Czechoslovakia, Great Britain, etc.

The table given below refers to statistics available for the latest years.

Alcohol production in different countries

Given in hectolitres at 100° Gay-Lussac

Countries	Years	Fruits and wines	Beet-roots	Molasses	Potatoes	Cereals or other materials	Various synthetic yeasts	Total
Austria	1932	76,575	..	135.460	..	..	62,630	198,095
Belgium	1932	..	..	89,300	..	17,900	59,600	166,800
Bulgaria	..	..	..	9,730	..	..	..	..
Czechoslovakia ..	1933	10,300	51,000	250,000	506,000	85,000	63,000	968,200
Denmark	1932	..	..	18,942	14,682	35,123	6,530	75,279
England	1932	..	..	500,000	..	212,200	26,000	738,000
Esthonia	1933	..	..	..	31,000	514	861	32,375
France	1932-33	949,896	2,446,892	830,278	..	23,167	11,888	4,262,121
Germany	1932	..	..	726,572	2,021,376	..	241,733	2,989,681
Hungary	1929	..	..	140,000	280.000	..	..	420,000
Jugoslavia	1931	..	..	118,000	31,900	..	..	140.300
Latvia	1933	..	..	8,200	46,200	..	..	54,400
Luxemburg	1932-33	652	..	1.542	..	23,143	..	5.637
Philippines	1933	..	..	100,000	..	..	..	..
Poland	1933	575	..	11,906	257,025	..	..	268,931
Rumania	1933	25,900	..	90,700 (1)	..	..	..	106,600 (5)
Sweden	1933	..	..	91,500 (2)	92,000	..	98,500 (3)	..
Switzerland ..	1932	107	..	3,283	..	..	8,878 (4)	108,765
United States ..	1933	..	..	1,822,000	..	134,000	229,000	2,198,000

(1) For the whole of the production, molasses and materials.

(2) For the whole of the production, bee-troots and molasses.

(3) Cellulose.

(4) Cellulose.

(5) This figure includes the whole of the alcohol bought by the monopoly. 96,415 hectolitres being imported.

Consumption of Alcohol in different countries for various purposes

The table given below shows the consumption of alcohol in each country for various purposes. It may be pointed out that, fortunately for public health, industrial uses are the most important, the largest amount being used for Heating, Lighting, and Carburation. In France, Germany and Czechoslovakia, the figures which have been given of the use for carburation are significant and show the tangible results of the policy of alcohol as a carburant.

Alcohol consumption in different countries

Given in hectolitres at 100° Gay-Lussac

Countries	Years	Alcohol for consumption	Chemical industries	Perfumery	Vinegar manufacture	Heating and Lighting	Carburant	Export
Austria	1932	66,244	5,585	781	8,021	70,904	4,852	..
Belgium	1932	63,800	22,584	4,976	15,000	14,800	440	..
Bulgaria	1932	46	786	..	2,645	4,828	..	..
Czechoslovakia ..	1932	162,000	14,035	..	20,062	181,781	586,116	..
Denmark	1932	7,683	14,988	..	4,015	42,835	120	..
England	1933	230,000	..	10,000	..	507,500	792	..
Esthonia	1933	19,940	3,277	..	..	..	3,358	..
France	1932-33	1,365,366	195,353	111,032	50,781	722,050	1,937,938	49,765
Germany	1932-33	399,446	..	30,386	143,000	838,170	1,571,231	..
Jugoslavia	1929	58,000	16,000	..	12,000	40,000	..	60,000
Latvia	1933	23,160	1,960	..	..	4,200	28,400	..
Poland	..	228,480	134,000	4,430	14,150	61,150	..	..
Rumania	1933	146,600	3,100	4,600	5,800	37,200	..	..
Switzerland	1932	38,750	25,700	2,217	..	54,700	..	..
United States ..	1933	Prohibition	951,000	30,000	130,000	866,000	..	..

Alcohol as a Carburant in the World

The following table indicates the commercial names and the composition of the mixtures rendered compulsory for the disposal of alcohol and of those which, although not compulsory, are to be found in a greater or lesser amount in some countries. The quantities of alcohol used for this application have been shown and calculated, as accurately as possible, as the percentage of alcohol used in this way by comparison with the total production of some of the countries.

Alcohol as a carburant in the world

Countries	Commercial name	Composition			Alcohol used in hecto litre	Per cent. of alcohol produced	Remark
		Petrol	Benzol	Alcohol			
Australia	Shellkol	85	..	15	..	..	
Austria 1932 ..	..	80	..	20	..	..	Comp.
Belgium 1932 ..	..	..	..	..	440	..	Do. petrol.
Bulgaria	..	97/95	..	3/5	..	..	Heavy oils.
Cuba 1933	Mofuco	37	3	60	..		
Czechoslovakia ..	Dynalkol	70	4	26	545,000	56·0	Comp.
..	1st September. 1932 ..	80	..	20		..	Do.
..	1st anuary, 1934 ..	70	..	30		..	Do.
Denmark 1933 ..	Used by "Die Danoise" only.	75	..	25	120	0·16	
Equador 1933 ..	..	80	..	20	..	..	Comp.
England	..	70	15	15	..		
France 1921—1931 ..	Carburant national ..	50	..	50	..	..	Comp.
1931	Do. poids lourd .	75	..	25	..	..	Do.
1932	Melange ternaire ..	Petrol ..	Benzol ..	13/51	1,937,938	44·0	Opt.
1932	Tourisme	90	..	10	..	..	
Germany	"Monopolin" ..	75	..	25	1,900,000	58·0	Comp.
Hungary 1933 ..	"Motalko" ..	80/70	..	20/30	240,000	41·0	Do.
Italy 1933	Legal mixture ..	80	..	20	..		
	Esso	Petrol ..	Benzol ..	Alcohol	..		
	Avion	Do. ..	Do. ..	Do.	..		
	Shell-Dynamin ..	Do. ..	Do. ..	Do.	Lubricant.		
Jugoslavia ..	Legal mixture ..	80	..	20	..	..	Comp.
Latvia 1933 ..	"Latols" May to September.	50	..	50	..	..	Do.
	October to April ..	67	..	33	28,400	52·0	Do.
Natal	Natalite	50	..	50	36,500	..	Favor legisl.
Panama	..	80	..	20	..	..	Ditto.
Philippines	"Gasanol"	70	..	30	100,000	100·0	Ditto.
Poland	Autos, tractor ..	85/70	..	15/30	21,150	7·8	Comp.
..	" ..	15/30	..	85/70	..	..	
Switzerland	Satisfactory tests made by Swiss Army						
Sweden	Lattbentyl	75	..	25	42,500	14·0	Comp.

Alcohol denaturing in various countries

Alcohol for consumption is a source of revenue to all the countries in the world. This alcohol is subject to very important consumption taxes, whereas alcohol for heating, lighting, or for the chemical industry is exempted from all or part of these taxes. It is essential that, this exemption having been obtained, the users will not be able to utilize this alcohol for private consumption. The alcohol is consequently denatured to prevent such utilization.

It is interesting to compare the various processes used for this purpose in the different countries in the following table :

Denaturing of alcohol in the world

Countries	Heating and lighting	Power-alcohol
Belgium ..	Bad taste alcohol .. 100 Benzol .. 10 Fuschine .. 0·5 gr.	
Bulgaria ..	2 litres methylene. 0·5 crotonaldehyde .. 1·0 gr. phenolphthalein. 0·2 grs. methyl violet.	0.25% Crotonaldehyde.
Chile	..	5 litres petrol. .. 20 c. c. ethylborate containing 0·2 gr. of borate.
Czechoslovakia ..	1 Kg. Esthonian Shale oil .. 0·4 methylene exices .. 0·4 dehydrated ethyl. alcohol as homogeniser.	98 ethyl. alcohol. 2 methyl. alcohol. 3 petrol.
Denmark ..	2·5 litres of the mixture (methylene 4 vols. and pyridic basis 1 vol.). 25 litres of paraffin oil is added.	2·5 litres of the mixture (methylene 4 vols. pyridic basis 1 vol.). 0·25 litres of paraffin oil is added.
Esthonia ..	1,500 heavy benzin. 750 birch tar or methyl. alcohol. 20 c. c. of a solution of ·4 gr. chlorahydrate of methyl-pararosaniline pe litre.	25 litres benzine or benzol.
		Up to the end of 1933
France ..	5·55 methylene exices ..	10 per 10,000 of Creosote oil distilling before 210 degrees 2 per 10,000 of ethylborate.
		From the end of 1933
		1 litre benzol 90°. ·30 benzine exices. 6 gr. anthracene. ·02 ethyl borate.

Countries	Heating and lighting	Power-alcohol
Great Britain ..	0·5 pyridine	25 petrol.
	2·5 methylene	0·5 pyridine.
	5·0 paraffin.	
Italy	..	Mixture of acetone oil and of complex hydrocarbon supplied by the State at 13·40 frs. per hectolitre.
Jugoslavia ..		3 litres petrol, S. G. ·73 to ·74 distilling 75° to 85°C.
Latvia		0·5 Crotonaldehyde.
		5·0 residue of the manufacture of lighting gas.
Poland.. ..	Denaturing with methylene ..	1·0% Naphtha solvent.
		15% naphthalene, pyridine, methyl alcohol, creosote oil, croton oil.
Luxemburg ..	10 litres benzol.	
	0·5 fuschine.	
	90 litres bad taste alcohol.	
Sweden.. ..	..	1% of crotonaldehyde.
		5% of petrol or benzol.

BUYING PRICE OF ALCOHOL ACCORDING TO THE RAW MATERIAL USED IN ITS MANUFACTURE

It may be stated that the prices can differ in each country only when there is no competition, i.e., if there is a monopoly of fact or of right. The figures given below in the table are stated in French francs per hectolitre of alcohol at 100°Gay Lussac. The calculations have been made as accurately as possible, taking into account the value of exchanges at the beginning of the year 1934.

It is astonishing to note the differences of price which exist between one country and another. This is due, of course, to the fact that all alcohol-producing countries apply customs duties preventing foreign alcohol from being imported and that on the other hand, while the Excise Department is controlling the distilleries, there is no possibility of fraud.

The protection afforded to the products obtained from the soil in each country, must in any case be pointed out, viz., beets, potatoes, and grain, while molasses alcohol is being considered everywhere as a by-product when compared with beets, potatoes, or grain.

Buying prices of alcohol by the monopolies

(Per hectolitre at 100° Gay-Lussac in French francs)

Countries	Beets	Potatoes	Molasses	Grains
Austria 1932	280·00	441·00	166·25	297·50
Czechoslovakia	231·40 173·35	231·40 173·35	.. 173·35	(6) 131·40 (7) 173·35
Esthonia 1933	..	218·50	..	218·50
France (4)	267·91	..	175·00	165·00
1933–34 (5)	276·80	..	190·00	170·00
Germany (1st October, 1933) ..	..	(1) 324 (2) 246 (3) 285	255·00	..
Latvia 1933	..	247·00	87·40	..
Poland 1933	..	197·00	162·00	..
Switzerland 1933	..	..	279·00	..

(1) By licence of 600 hectolitres and for 50 per cent. of the quota.
(2) By licence of 600 HL and for 50 per cent. of the balance.
(3) By licence for more than 600 hectolitres.
(4) For raw spirits.
(5) For rectified alcohol.
(6) Agricultural Distilleries.
(7) Industrial Distilleries.

SELLING PRICES AND FISCAL TAXES

As in the former statement, the information which has been possible to collect under this heading is also unfortunately not quite complete.

It must be stated, however, that in every country alcohol sold for carburation is always supplied at a lower price than the average buying price paid by the monopoly to the manufacturers of alcohol. This leads to the conclusion therefore that all these countries are unanimously desirous (perhaps for different reasons but with the same results) not only to encourage the production of alcohol but to dispose it off in competition with petrol, which all of them use and which has generally to be imported.

It will be evident from the table that is given below that the policy of all the countries is the same on this point.

Selling prices of alcohol according to use, taxes included

(In French francs per hectolitre at 100° Gay-Lussac)

Countries	Year	Drinking purposes	Industry	Vinegar	Perfumery	Denaturized	Fuel
Austria ..	1932	2,002	434	434	2,002	364	161
Bulgaria ..	1932	..	..	..	..	774	..
Cuba ..	1932	..	..	..	..	..	..
Czechoslovakia ..	1933	2,437	273	650	2,437	273	375
Denmark ..	1932	6,336	..	..	2,160	180	..
Esthonia ..	1933	1,866	437	1,866	1,866	322	260
France ..	1933	(1) 3,607	500	525	2,830	200	(3) 112
		(2) 3,157	..	..	..	..	(4) 155
Germany ..	..	2,400	240	510	1,400	270	300
Great Britain ..	1932	..	139	..	..	278	200
Italy ..	1933	..	..	..	..	..	(5) 174
							(6) 194
Latvia ..	1933	2,926	608	257	..	266	106
Poland ..	1933	2,430	364	324	1,350	174	114
Rumania ..	1933	..	..	..	930	375	..
Sweden ..	1933	..	..	..	..	..	176
Switzerland ..	1933	2,530	205	..	1,055	215	..
United States ..	1933	..	..	..	..	150	120

1. Alcohol from the monopoly for the preservation of fruit.
2. Alcohol from the free market. Heavy weight.
3. Dehydrated alcohol-fuel.
4. Tourisme dehydrated alcohol and ternary fuels.
5. Alcohol a 95° for carburation.
6. Dehydrated alcohol for carburation.

Amount of taxes per hectolitre at 100° *Gay-Lussac in French francs*

Countries	Years	Drinking purposes	Perfumery	Industry
Austria	1932 ..	1,057	..	..
Bulgaria	1932 ..	1,576	..	300
Cuba	1932 ..	..	320	960
Czechoslovakia	1933 ..	2,010	2,010	108
Denmark	1932 ..	5,860	1,836	21
Esthonia	1933 ..	Included in the selling prices.		
France	1933 ..	2,607	2,330	..
Germany	..	Included in the selling prices.		
Great Britain	1932 ..	5,700	2,350	10
Italy	..	..	..	..
Latvia	1933 ..	Included in the selling prices.		
Poland	1933 ..	1,620	1,160	175
Rumania	1933 ..	..	..	..
Sweden	1933 ..	..	..	
Switzerland	1933 ..	Included in the selling prices.		
United States	1933 ..	Ditto.		

Financial results of monopolies

On this particular point, the writer's information is still more incomplete and extremely difficult to be presented in a tabular form. We must note from this fact that the balancing of budgets is always obtained notwithstanding the fact that the alcohol sold for Carburation constitutes a certain loss. But this loss is compensated either by the sales of alcohol-drink at high prices, or by the money which is obtained from the right of consumption of those drinks, or finally by a levy made by the State on the imported petrol.

In all cases the policy remains the same, namely, to insure an agricultural production which seems essential to the prosperity of the country.

In the table which follows the quantities are given in hectolitres and the currency in French francs :

Countries	Years	Production	Receipts	Expenses	Profits
		HL	Frs.	Frs.	Frs.
Austria ..	1932 ..	198,095	..	..	3,500,000
Czechoslovakia ..	1933 ..	..	..	..	417,000,000
Esthonia ..	1933 ..	32,375	44,300,000	8,100,000	36,200,000
France ..	1932 ..	3,312,225	1,166,899,654	1,014,647,652	152,252,001
Latvia ..	1933 ..	..	96,900,000	34,200,000	62,700,000
Poland ..	1933 ..	..	882,000,000	268,800,000	613,200,000
Rumania ..	..	..	..	..	50,850,000
Switzerland ..	..	..	75,000,000	38,500,000	36,500,000

CHAPTER IV

AGRICULTURAL INTEREST AND STATE LEGISLATION INTRODUCED IN THE VARIOUS COUNTRIES FOR THE DEVELOPMENT OF POWER-ALCOHOL CONSUMPTION AND MANUFACTURE

For the past many years and specially since the Great War, a great deal of interest in the alcohol fuels has been shown in many countries, not possessing their own petroleum resources. These countries have, naturally, been rather anxious regarding their fuel supplies in times of national stress, when foreign sources of supply are cut off completely or else considerably reduced, and they have directed their attention to the production of liquid fuels from their home resources. Moreover, during the past few years of economic depression, agricultural industries have suffered as much, or even worse than most other enterprises and at the same time extreme nationalistic tendencies have been the cause of the erection of extensive tariff barriers. Such circumstances as these all occurring together have given a big impetus to the development of alcohol fuels as a means of helping agricultural industries, of reducing adverse trade balances, and of reducing imports of foreign materials. That such a development has come about during a period of unprecedented petroleum surplus is to be regretted in every way, but the fact remains that by the imposition of taxes upon imported petrol and legislature, demanding admixture of home produced alcohol with imported motor fuels, most of the European countries have reduced their fuel imports considerably. It may as well be pointed that the development of a farm-product alcohol industry has not been considered solely as an emergency measure. If undertaken properly, it has been considered to the interest of both the users of motor fuel and the farmer to adopt it as a long time programme. The fact that there is now a surplus of crude oil and gasoline must not lead us to the belief that the oil resources of the world are inexhaustible. Moreover, the manufacture of petroleum substitutes from other than farm products may be developed on a low cost basis. On the other hand, a well planned agricultural programme or policy maintains the renewable resources of the country indefinitely. This consideration of a long time programme has warranted the adoption of definite Government policies in many of the countries for encouraging, or at least protecting, the development of the alcohol industry and the use of alcohol in motor-fuels, either by private capital and management or by Government loans and Government operation or regulation.

A summary is given below showing the present position of the alcohol fuels in the various countries of the world and the Legislative measures that have been deemed necessary by the State to achieve the desired

result for the promotion of agricultural interests by encouraging the consumption of power-alcohol. It is to be pointed out that among these 40 nations, ten possess a State monopoly or a monopoly of fact recognized by the State. This monopoly is either total for alcohol from all sources, or partial, applying only to industrial alcohol, while alcohol for drinking purposes is retaining its entire freedom as regards the production and sale.

These countries are: Czechoslovakia, Denmark, Esthonia, France, Germany, Hungary, Latvia, Poland, Rumania and Switzerland.

1. *Argentine*—FREE: Until now no measure has been taken in favour of power-alcohol, as Argentine possesses rich petroleum beds with which the national requirements can be filled. At the present time in order to meet the wine and sugar crises the Argentine Legislature is trying to adopt itself to what has been done in other countries in favour of power-alcohol. Investigations are in progress.

2. *Austria*—MONOPOLY: Alcohol is obtained almost exclusively from the treatment of local molasses (68 per cent.). The increase of alcohol consumption leads to the treatment of more raw materials containing alcohol and result in their increased value. Law of 28th January, 1931, article 15, made it compulsory to mix 25 per cent. of alcohol to petrol and specified that the price per hectolitre of alcohol for mixing purposes should be equal to the wholesale price of petrol. This clause was burdensome to the budget and was reducing the consumption. It has been abolished on 4th September, 1933. The monopoly will thus be able to increase the sale of power-alcohol.

3. *Belgium*—FREE: No measures favouring the use of alcohol as fuel. As raw materials used for the manufacture of alcohol are not benefiting by any protection, a more or less large consumption of these products cannot modify the price of farm commodities which are used in distillation. On the other hand, the Belgian Government being mainly concerned with the balancing of the budget do not encourage the use of alcohol fuel, its substitution to petrol, litre for litre, entails the loss of a tax of 1·54 francs.

4. *Brazil*—COMPULSORY: Decree of 1st August, 1931; compulsory to mix 10 per cent. alcohol to petrol. Not applied, being unable to supply alcohol. The Government try to come to the help of the decreasing sugar industry and to this effect a decree has been promulgated which forces importers of petrol to obtain the alcohol necessary for compulsory mixing. In actual practice the decree remained dormant, because to enforce it, it would have been necessary to build distilleries producing absolute alcohol. To do this foreign capital would be needed. Up to the present the results are small, as only five distilleries produce alcohol

5. *Bulgaria*—FREE: At the present time through a lack of the markets large quantities of molasses and of maize are destroyed. More than 20,000 tons remain without being used (equivalent to the production of about 3 years). The adoption of the law proposed for the compulsory mixing of alcohol to petrol would entail the manufacture of 26,000 hectolitres of alcohol, making it possible to use all the molasses and a large part of the maize available.

A project is in hand to make the mixing of 25 per cent. alcohol to petrol compulsory. The measure would considerably help the agriculture.

6. *Chile*—COMPULSORY: The Chilian decree of 26th September, 1933, making it compulsory to mix alcohol with petrol has solely in view the help of the agricultural industries of sugar and wine. According to economical considerations of these two agricultural branches, the compulsion of taking up alcohol fixed by decree can vary from 1 to 25 per cent. of the volume of imported petrol. The exact amount is fixed every year. Importers can free themselves from this compulsion by payment of 41·50 francs per quintal. The price of alcohol is fixed by decree, it shall not exceed the price of petrol by more than 10 per cent. The decree of 28th September, 1933, fixes the quantity of alcohol to be purchased at 6·25 per cent. of the quantity of petrol imported and the price of dehydrated alcohol at 112 francs per hectolitre.

7. *Costa-Rica*—FREE: The Law of August, 1933, foresees that the petrol monopoly shall investigate the technical possibilities and economical advantages of mixing alcohol to petrol.

8. *Cuba*—FREE: Alcohol mixed with petrol is free from tax. The percentage is optional.

9. *Czechoslovakia*—COMPULSORY: Compulsory mixing is introduced from 1st September, 1932, Laws of 7th June, 1932, (No. 85), and Government decree (No. 127) of 22nd June, 1932.

In the mixture alcohol alone is free from consumption tax but it is subject to a trading tax. Afterwards the mixed petrol must have a Specified Gravity lower than 0·79 at 15°C. The prices paid to industrial distilleries is $\frac{3}{4}$th of the price paid to agricultural distilleries. The prices of petrol are from 136 to 141 francs per hectolitre, the Dynalcol 182 francs, and the legal mixture sells at 136 to 149 francs per hectolitre.

Laws rendering the use of power-alcohol compulsory show all the interest which official circles attach to the disposal of alcohol of agricultural origin. The Minister of Finance has even taken the initiative of a plan to undertake the culture of beet. The fundamental arrangements of the proposition consist in reducing the sowing of cereals to the benefit of sugar-beets, making it possible on the one hand to utilize the whole exportation quota, viz., 5,700,000 quintals, and on

the other to raise to 50 per cent. the alcohol percentage of compulsory mixture.

10. *Denmark*—MONOPOLY: The monopoly is actually in the hands of "Distilleries Danoises." Production of alcohol for consumption is fixed by quota at 13,200 hectolitres, but this figure is not reached. The use of any other fuel than petrol is prevented by law.

In this country the alcohol industry has a great influence on agriculture as regards raw materials (potatoes 20 per cent.) and malt residues.

Interested parties wish the compulsion of the use of power-alcohol in order to increase the development of materials producing alcohol.

11. *Dutch Indies*—FREE: The use of alcohol is limited by the Excise taxes and the denaturant (methylene). On the other hand the use of alcohol fuel would gravely affect the interest of the Royal Dutch and Standard Oil Concession holders at Java, Sumatra and Borneo.

12. *Ecuador*—COMPULSORY: National Congress decreed on 6th September, 1933, the use of compulsory mixture of alcohol-petrol in order to come to the help of the sugarcane growers. Decree of 6th December, 1933, compelled the use of a mixture of alcohol-petrol.

13. *Egypt*—FREE: No particular regulations. The sole use of molasses is for the production of alcohol.

14. *Esthonia*—MONOPOLY: Laws of 1929 and 1932. Alcohol is a State Monopoly. It is almost exclusively manufactured from potatoes. The proportion of the crop worked to this effect represents 4·3 per cent. of the total production.

The Agricultural interests are asking the Government in a pressing way to pass a law rendering compulsory the mixing of alcohol to petrol, in order to have a wider outlet for the only industrial culture of the country. Until now the interests of the National producers of shale-oil have prevailed and the measure tending to open a new outlet for alcohol has always been set aside. The fight continues more and more violently as the agricultural crisis is becoming more severe.

15. *Finland*—FREE: Parliament is investigating a project to render compulsory the mixing of 8 to 10 per cent. alcohol to petrol. It tends to utilize sulphite liquors from wood pulp works with the idea of assisting that industry.

16. *France*—COMPULSORY: Law of 23rd February, 1923, article 6. Importers were compelled to take up from the State a volume of alcohol corresponding to 10 per cent. of the petrol imported. The decree of 31st May, 1923, stipulated that the alcoholized fuel shall contain from 48·5 to 52·5 per cent. of alcohol by volume. It also specified the conditions of volatility and the stability of the mixture.

Law of 4th July, 1931, Article 9, forced compulsion of mixing 20 to 26 per cent. of alcohol to petrols other than "Tourisme" petrol. The mixture was sold under the name of "Carburant poids lourd" (order of 26th October, 1931).

Law of 31st March, 1932, Article 36. Importers who have not taken up their alcohol within the prescribed time will be liable to a penalty of 0·25 francs per hectolitre per day. Order of 1st July, 1932, referring to the mixtures of hydro-carbons and of alcohol other than "Carburant poids lourd" laid down that the proportion of alcohol must be between 13 to 51 per cent. of the mixture. Law of 31st March, 1933, limited the production of beet-alcohol to 2,300,000 hectolitres calculated at the parity of the price of sugar. Order of 25th July, 1933, authorized the mixing of 11 to 15 per cent. of alcohol to "Tourisme" petrol which was always to correspond to the characteristics specified by the Ministerial order of 20th December, 1925. The mixture was to be sold under the name "Essence Tourisme." Order of 3rd October, 1933, made compulsory the addition of 0·5 gr. of rhodamine B as a colouring matter to "Carburant poids lourd."

The culture of the beets is an agricultural necessity for the north and the Parisian basin. As the sugar manufacture is not officially controlled by quotas, any development of the consumption of alcohol is to the advantage of the beet producers. In the present state of things, alcohol fuel constitutes an important outlet for the French distilleries (2 million hectolitres in 1932-33). Up to the present time the increase of the quantities of alcohol used for carburation is mostly due to legislative measures taken in its favour. For the future, on account of the special properties of alcohol and the very marked tendency which the motor car manufacturers have to increase the compression ratio of the engines in order to decrease the consumption, the addition of alcohol to petrol will become a technical necessity.

In France this alteration will be hastened by the modification made since 1st February, 1934, to the basis of taxation of motor cars, the quarterly tax calculated according to a conventional formula of the power of engines being replaced by an extra tax of 0·5 francs per litre of petrol. This alteration is particularly desired by the parties interested in the beet culture.

17. *Germany*—MONOPOLY: Decree of August, 1930, enforced the mixing of 2½ per cent. by weight of alcohol to all imported and home produced gasoline. This amount has since been increased to 10 per cent. The decree, however, permits alcohol bought by gasoline producers to be sold back to the alcohol monopoly at a lower price. In actual practice most importers and producers of gasoline mix the alcohol which they are compelled to buy with a part of their gasoline. A German national fuel has recently been proposed consisting of 70

per cent. gasoline, 10 per cent. alcohol, 10 per cent. methanol and 10 per cent. benzole, but this has met with serious opposition from the benzole producers and has not yet been enforced by law. As in most countries which use alcohol fuels, the problem in Germany is to obtain sufficient alcohol of the requisite quality for blending with gasoline.

18. *Great Britain*—FREE: Law of 1923. Denatured alcohol can be used for carburation—Exemption of taxes when so used.

In Great Britain alcohol has been manufactured until now from imported raw materials. The development of the production therefore cannot benefit agriculture. On the other hand this country likes to liberate itself from the dependence in regard to liquid fuels and is recently trying to start an industry of synthetic fuels. According to Dr. Ormandy, it is likely that alcohol before long would be a product of the petroleum industry. Several plants are already manufacturing alcohol including Southampton.

19. *Greece*—FREE: Although no special measures have been taken until now, the attention of the technical men of Greek Public Bodies is drawn to the alcohol problem. The utilization of the alcohol mixture will present the triple advantages of—

(*i*) Supplying markets to wine producers which are every day seeing outside markets being closed for them;

(*ii*) Giving a renewed activity to the industry manufacturing the alcoholic fuel;

(*iii*) Answering partially the necessities for national defence.

The quantity of alcohol to be mixed yearly will be approximately 63,000 hectolitres.

20. *Haiti*—FREE: There are no official regulations to this effect in the island. Alcohol manufacture is the only use for molasses.

21. *Holland*—FREE: No measure has been taken in favour of alcohol. Petrol is very cheap (130 francs per hectolitre). Measures for agricultural help only concern beet as raw material for the sugar industry (80 francs per ton for beets).

22. *Hungary*—COMPULSORY: Law No. 23 of 1927, applied on 1st September, 1929, laid down that petrol to be used in engines must be mixed with a proportion of 20 to 30 per cent. of alcohol. The specific weight of commercial petrol must be between 0·736 and 0·745. Light petrol and inferior to 0·735 is exempted from compulsory mixing. Light petrol is sold at 2·31 francs, while "Motalco" sells for 1·87 francs and its consumption represents 86 per cent. of the total amount of fuel used in Hungary.

Alcohol is produced from molasses (33 per cent.) and from potatoes (67 per cent.). The increase of consumption following the law of 1929

for compulsory mixing of alcohol to petrol has made possible the disposal of a considerable amount of agricultural products.

23. *Italy*—RESTRICTED FREEDOM: The use of alcohol is regulated since 1923. Mixing is optional. Law No. 874 of 18th June, 1931, made it compulsory for importers to take up a certain amount of manufactured or imported alcohol. The percentage periodically fixed for 1933 was 4·28 per cent. of the petrol imported.

Alcohol manufacturers, including those of alcohol extracted from wine as well as importers, were required to place at the disposal of the petrol importers 25 per cent. of their production or of their importation of alcohol at the price of 174 francs per hectolitre or of 194 francs for absolute alcohol.

The Italian problem of alcohol has particularly in view the help to the wine market.

24. *Japan*—FREE: The law on alcohol stipulates that alcohol used as fuel will be free from fiscal taxes.

25. *Jugoslavia*—FREE: Order of 27th September, 1932, on the application of the tax of 18th April, 1932. Compulsory mixing of 20 per cent. alcohol to petrol was enforced. Order of 22nd November, 1933, cancelled the compulsion prescribed by the former tax and established optional mixing. The latter is assisted by a law which raises the tax on pure petrol at 5 dinars per kilogram or 136 francs per hectolitre.

For politicial reasons, fruit alcohols have been exempted from the consumption tax from 18th April, 1932. This measure would have placed the alcohol industry out of work, if it did not render the mixing of alcohol with petrol compulsory. The decree foreseeing the compulsion organized the alcohol monopoly and fixed the quotas of agricultural distilleries at 30,000 hectolitres and of industrial distilleries at 70.000HL. The quantity corresponds to the use of 1/5 of the average maize crop. The results obtained have been very satisfactory. Since 22nd November, 1933, compulsion has been removed, but pure benzine is subjected to a higher tax than the one applied to petrol-alcohol mixture.

The manufacturing possibilities of 44 agricultural distilleries are of 60,000 hectolitres yearly. Those of the industrial distilleries, eleven in number, are of 240,000 hectolitres.

26. *Kenya*—FREE: The local production of alcohol fuel is foreseen by the treatment of maize, molasses, and other national products.

27. *Latvia*—MONOPOLY: Law of 20th May, 1933, made the mixing of alcohol with petrol compulsory.

Alcohol is manufactured in the proportion of 85 per cent. with home-grown potatoes. Any increase in the production of alcohol corresponds with an increased outlet for potatoes and beets resulting in indirect increased value. It is to be noted that the mixtures contain 50 per cent. alcohol and that no particular difficulties have been mentioned by users.

28. *Luxemburg*—FREE : Power-alcohol is not used. The Ducal order of 29th July, 1926, specifies the conditions for the denaturing of alcohol so as to free it entirely from tax.

Agricultural conditions are the same as in Belgium.

29. *Natal*—FREE : The legislative arrangements reduce the tax to 24 francs per hectolitre of alcohol mixed with petrol. Very active sale of "Natalite" with excellent results is going on notwithstanding the efforts of the petrol importers against its use.

The question presents itself in Natal in the same manner as in the Philippine Islands. Molasses alcohol imposes itself by its qualities and makes it possible to increase the value of a by-product without any other possible utilization except for alcohol. This utilization is encouraged by a slight decrease of the tax on petrol used for the mixing.

30. *Nicaragua*—FREE : No law exists in this country favouring the use of alcohol for carburation, but technical tests are made by interested parties. Many individuals use the mixture of alcohol-petrol with success.

31. *Norway*—FREE : In 1930 an extra Parliamentary Committee has been formed to investigate the use of cellulose alcohol as fuel.

32. *Panama*—RESRICTED FREEDOM : Law no. 34 of 1932. Decree of August 17, 1933. The taxes applied to petrol are as follows : per hectolitre of pure petrol 26·75 francs, while for the blend mixed with 25 per cent. alcohol only 13·35 francs.

The selling price of the mixed alcohol-petrol fuel shall not be higher than 41·50 francs per hectolitre. A tax of 94·0 francs per hectolitre is levied on molasses alcohol to be used for consumption.

The compulsion of mixing alcohol to petrol, applied since 1st December, 1933, is meant to allow the utilization of home molasses, and to come to the help of the sugar industry indirectly. It is forbidden to use the raw juice and the molasses in the same works.

33. *Philippines*—FREE : Free mixing is made by the sugar companies. The sale of "Gasonol" represents one-third of the liquid fuel sold. The demand is regularly increasing and the whole of the molasses produced in the island will have shortly been treated. The chief reason for this success is the technical value of the fuel and its low cost. Petrol sells for 84 francs and "Gasonol" for 77 francs per hectolitre.

The use of alcohol being very general, the numerous distilleries in operation in the islands are all active and are in course of extension. This activity benefits not only the distillers but it is also a source of a profit to sugar manufacturers and agriculturists, and particularly to the State, which levies a heavy manufacturing tax on alcohol. It is foreseen that the revenues from this tax might reach a higher figure than the total of the taxes which are applied at present to petrol imported from the United States.

34. *Poland*—MONOPOLY : Law of July 2, 1932, established the monopoly and gave the right to the Minister for applying the compulsory mixing of alcohol to petrol (article 48). At the present time no use is made of this power. Importers who are selling alcohol-petrol mixtures must obtain a licence from the monopoly and agree to buy certain quantities of alcohol which are fixed beforehand. Petrol and alcohol entering into the composition of the mixture are exempt from any tax. The price of alcohol containing fuel is not allowed to exceed the price of petrol.

The sandy soil of Poland compels the culture of potatoes as a basis for the varied succession of crops. This culture represented, in 1933, 2,749,000 hecta-acres for 30 million tons. After Germany, it is the largest producer in Europe. The problem of the manufacture of alcohol from potatoes is on that account most important for agriculture and governs all the agricultural economy of the country. As the consumption of alcohol as a drink is decreasing, all the efforts must be centred on the utilization of power alcohol. The decrees taken by the State emphasize all the national importance of this question.

Poland possesses 1,487 agricultural distilleries and 24 industrial distilleries. As a result of the 1932-33 campaign, 1,360 agricultural distilleries and 16 industrial distilleries are working.

35. *Queensland* (*Australia*)—COMPULSORY : Fuels with a basis of molasses alcohol are manufactured by various sugar companies. The Queensland Government have decreed that motor car petrol distributors must take up a certain percentage of alcohol at a fixed price.

36. *Rumania*—MONOPOLY : Since 5th May, 1932. Fruit alcohol manufactured by the growers is kept out of the monopoly. The buying and selling prices are fixed every year by the monopoly.

As in all agricultural countries, the development of the production of alcohol from agricultural products opens a market for raw materials (vine, potatoes, cereals). When production is the object of a complete monopoly the increase of consumption means an increase of fiscal revenue.

37. *Sweden*—FREE : The alcohol fuel utilized in Sweden comes exclusively from the residual lixivium of wood pulp treated with sulphurous acid. It is free from tax. However, from 1st July, 1934, it has been taxed on the basis of 41·00 francs per hectolitre. The mixture of alcohol-petrol sold at 155 francs per hectolitre is cheaper than pure petrol.

The use of alcohol for carburation makes it possible to utilize an important by-product (142,000 hectolitres in 1929-30) and to contribute to the activity of a national industry. According to the specialists like Professor Hubendick, the production could reach 500,000 hectolitres for a country of 6 million inhabitants.

38. *Switzerland*—MONOPOLY : Law of 2nd June, 1932, came into operation on 1st January, 1933. The right of manufacturing, importing, or selling belongs to the Confederation. This right is granted to Co-operative Societies or private undertakings. The domestic production of fruit alcohols is staying out of the monopoly.

The licence of working with potatoes is granted only if it is impossible to use them in a more rational way. Each work is given a quota. The Excise decides if the concession holder can use his quota and the amount. The buying prices are such that distilleries can pay the producers a fair price. Alcohol for drinking purposes is sold in minimum quantities of 150 litres.

In this country the utilization of alcohol is more important than its production. The interest of alcohol utilization takes the lead over its production. In fact the new legislation aims particularly at decreasing the consumption of drinking alcohol in developing industrial uses. The monopoly being of a fiscal character, any development of the consumption entails a development of the revenue.

39. *Turkey*—FREE : The Minister of Finance has asked the alcohol monopoly concern to investigate the possibility of producing a national alcohol fuel.

40. *United States*—FREE : Although the largest producer of petrol, the United States foresees the utilization of alcohol as a fuel. The proposed law backed by the Secretary of Agriculture, Mr. Wallace, aims at coming to the help of the maize producers. It is possible that this scheme will be included in the group of measures proposed by President Roosevelt.

The proposed scheme would impose on the supplier of petrol the compulsion of taking up to a certain percentage of alcohol (2 to 5 per cent.). The mixing would not be compulsory, but a consumption tax on alcoholic petrol would be lower than the tax applied on pure petrol-francs 3·98 against Francs 11·1, per hectolitre.

This measure is strongly opposed by the refiners, who fear that a part of their market would escape from them. (Total consumption of petrol is 580 million hectolitres for 24,100,000 motor cars per year.) No commentary is required after the perusal of the preceding pages to show how the question of power-alcohol is making headway every day. In all climates, at all latitudes, and in all parts of the world alcohol is being used in explosion engines. From the information that has been possible to collect the general public can form its own opinion on the value of

alcohol fuel. Such a universal use could not have been taken place, if all the disadvantages attributed to alcohol had been correct.

It will be noticed that the use of alcohol is increasing, notwithstanding its relat vely high manufacturing price in most cases. The reason for this will be found in the fact that the Governments of these countries have understood that developing a market for it is ensuring work to their agriculture and to their national industry. It must not be overlooked, however, that some of the countries have developed its use as a carburant without any Government protection and solely on its own merits.

It is also quite certain that if the use of alcohol fuel has made such a large development as the above report is showing, it has not been without intense and even heated discussions taken place regarding it, and all the tenacity of the scientists, technicians and experimenters was required in order that their point of view might prevail.

A passing reference may also be made to the keen opposition met in its development from the big oil groups at first, who could not sympathetically see their embryotic competitor gradually taking ground from them. Ways and means to keep their goodwill and co-operation have, however, been found possible in every case either by legislation, preferential tax, or on the merits of the alcohol itself.

CHAPTER V

Different processes for the dehydration of alcohol

There are two different methods in use at the present time for the dehydration of alcohol :

1. The Azeotropic, and
2. The Salt dehydration.

1. *The Azeotropic Processes*

The old process of dehydrating alcohol by distillation with quicklime is expensive and has now been almost completely superseded by cheaper and modern processes. The one process almost universally used today is based upon the property which hydrated alcohol has of yielding with certain hydrocarbons (such as benzine, etc.), a ternary azeotropic mixture, i.e., a ternary mixture whose boiling point is lower than that of each of its components.

In 1922, Guinot proposed a modification of the original Young process, employing Benzine as the hydrocarbon which is now used throughout the world. By certain patented modifications it is now possible to make dehydrated alcohol continuously from ordinary 95-96 per cent. alcohol or even from fermented mash. The actual costs of this process, exclusive of royalties, have been estimated by large producers of alcohol not to exceed 1 cent. per gallon or about ½ anna per gallon.

Mehods of removing water from alcohol by azeotropic distillation depend to a certain extent on a particular design of apparatus. A column apparatus provided with about 50 plates with bells or tunnels is employed, and an agent for removing the water, for example benzine, is introduced at the top and below it the alcohol to be dehydrated.

By this means there is formed an azeotropic ternary mixture, in the present example alcohol-benzine water, which carries the water of the alcohol with it as one of its constituents and is continuously drawn off from the top of the column into a condenser from which it is partly returned again to the column as reflux and partly drawn off through a cooler for the purpose of being worked up. The alcohol flows out at the bottom of the column free from water after the water and the dehydrating agent have been separated on the passage downwards from one plate to another.

That part of the ternary mixture to be worked up next flows through a separating vessel in which it is separated into two layers having a high and a low water content. This process is hereinafter termed decantation. The layer having a low water content, which consists chiefly of the dehydrating agent, is returned directly to the dehydrating column, whereas that having a high water content must be subjected to a separate treatment in order to be able to remove the water which is contained in it.

In view of the fact that, when using one of the usual dehydrating agents, the layer having a high water content contains appreciable amounts of that agent, it is necessary to separate the dehydrating agent before the water can be removed. There are two ways in which this can be done. Either the layer having a high water content can be washed in a separate vessel, and the dehydrating agent which is insoluble in water thereby separated from the aqueous alcohol; or the dehydrating agent may be distilled from the aqueous alcohol in a separate auxiliary column apparatus.

Benzine or petrol or a benzine-petrol mixture have hitherto been the chief dehydrating agents employed on the continent and in the United States of America. The main factors which determine the suitability of the dehydrating agent are the composition and the method of decantation of the azeotropic mixture, which contains this dehydrating agent as a constituent. A dehydrating agent is the more useful the more water is present in the ternary mixture of the layer having a high water content, and also the greater the volume which this quantity of water occupies in the space required by the layer having a high water content. These two factors are called Dehydration Efficiency (DHE) and Decantation Efficiency (DCE) and they can be numerically defined as follows:

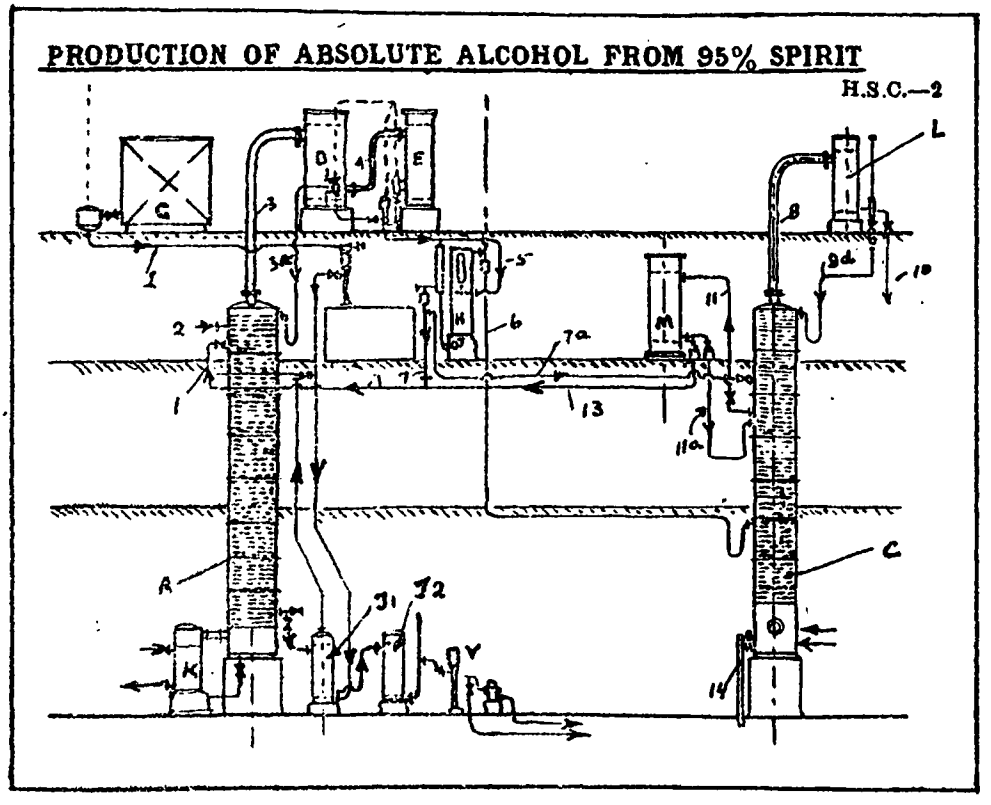
$$\text{DHE} = \frac{\text{Water content of the high water layer} \times 100}{\text{Volume of the ternary mixture}}.$$

$$\text{DCE} = \frac{\text{Volume of the high water layer}}{\text{Water content of the high water layer}}$$

Hence, the ideal case would be dehydrating efficiency of 100 and a decantation efficiency of 1.

In addition to possessing the above stated properties the dehydrating agent must also be indifferent to alcohol, must remain undecomposed at high temperatures, and must have a latent heat and specific heat as low as possible. These requirements are only incompletely met by the dehydrating agents that have been used so far.

An apparatus for carrying out the above described process is illustrated by way of example in the drawing below :



According to exact measurements of the steam used in large-scale operations, only 10 lb. of steam are required for one gallon of absolute alcohol manufactured. The consumption of water amounts to 4·1 c.ft. per gallon of absolute alcohol produced. The absolute alcohol is obtained with a strength of 99·8 to 100 by weight. In order to obtain the steam consumption stated above, a 94 per cent. by weight of crude spirit in a liquid condition (not in the condition of vapour) must be employed as the starting material and the columns must be well insulated.

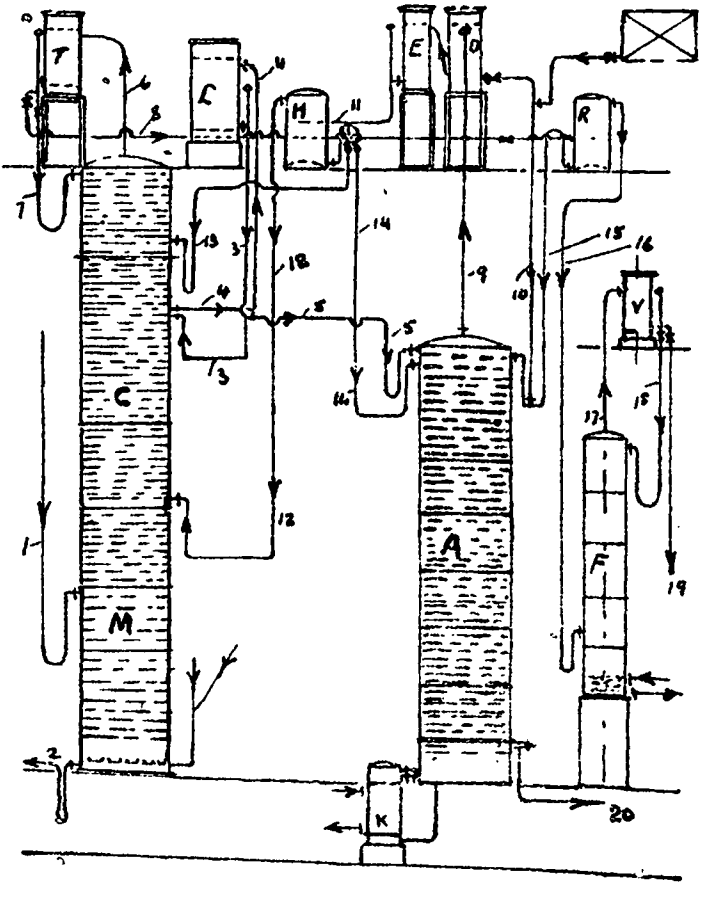
As has been pointed out before, the new process is not only suitable for dehydrating high proof alcohol, but it can also be used to the same advantage for the manufacture of absolute alcohol directly from fermented mashes, wort or liquors without an increase in the number

of columns being necessary. In this case the fermented mash or similar spirituous material is de-alcoholized in the same column as that in which the concentration of the acqueous alcohol obtained in the dehydration of alcohol is effected. In consequence of this arrangement the heat of the vapours arising from the mash is utilized to concentrate the aqueous alcohol obtained during the dehydration process.

An apparatus for carrying out this process is illustrated by way of example in the drawing below :

H.S.C.—3

PRODUCTION OF ABSOLUTE ALCOHOL DIRECTLY FROM MASHES



By means of special connexion between the column it is possible to obtain absolute alcohol directly from the mash without any auxiliary columns being necessary. The columns M and C can, of course, also be constructed in two parts.

The heat efficiency of the azeotropic processes becomes still more favourable if preheaters are interposed in order to transfer wholly or partly to the liquids to be vaporised the useful heat of evaporation and the specific heat of the vapours withdrawn from the column which are to be condensed.

There naturally exists the possibility of converting existing rectifying plants into plants for the production of absolute alcohol by this process, which is at present being done by a number of American and Continental firms dealing in distillery apparatus.

Various patents have been issued in recent years pertaining to improvements in the details of the above mentioned process both in regard to the design of the apparatus and the use of the dehydrating agent. Among these the outstanding patents are of the following :

(1) Kubierschky's first and second method (Germany).

(2) Steffend's Process (American).

(3) Rodebush Process (American).

(4) Keyes Process—first and second methods (American).

(5) Recard Allenet Process (Usine de Melle-French). A number of patents are held by this firm.

(6) U. S. Industrial Alcohol Co. (American) holds a number of patents of Mr. A. A. Backkaus.

(7) E. Merck, Chemical Works (Germany.)

A number of these patents and specially the Usine de Melle of Paris claim that the steam requirements of their process (fourth technique) have been reduced to such an extent that it is now possible to produce 99·8 per cent. absolute alcohol at no extra cost than that necessary for the production of rectified spirit (95-96 per cent.). In other words, the dehydration and the purification of the alcohol are generally effected free of cost excepting for the very small loss of entrainer, this amounting to about 1 part per 1,000 parts of alcohol dehydrated. Such loss is largely counterbalanced by the high yield—96 to 98 per cent. of good quality alcohol directly obtained. The Drawinol process of E. Merck, the Backkaus process of U. S. Industrial Alcohol Co., and the Acme Copper Smithing and Manufacturing Co., of Philadelphia, all claim similar advantages.

Of all the existing processes, however, the process of Usines De Melle of Paris is the most popular. At the present time, 80 per cent. of the total number of absolute alcohol plants at work throughout the world

use the " Usines de Melle " methods and are capable of producing 19,000 hectolitres of absolute alcohol per day. Their fourth technique has obviously many advantages to its credit because—

(1) (*a*) It brings about actually in single operation the distillation and dehydration of alcohol, starting from fermented wash.

(*b*) At the same time reduces the losses (usually between 0·5 and 1 per cent.) which are inevitable in the intermediate distilling or rectifying operation.

(*c*) It diminishes to a minimum the cost of handling and storage owing to the entire absence of any intermediate product such as raw or rectified spirit, since fermented wash is introduced at one end of the apparatus and absolute alcohol flows out from the other.

(2) Because in this process the heat necessary to exhaust the fermented wash of alcohol is sufficient in most cases to carry out all other steps in the operation. Consequently, this method of manufacturing absolute alcohol is no more costly than the production of raw spirit of high concentration by the ordinary method. It may indeed be said that the method carries out the dehydration of alcohol free of cost.

(3) Owing to the minimum cost of steam, the outlay on water is also minimum.

(4) This method makes it possible to obtain in an absolutely anhydrous condition as much as 97—99 per cent. of the total alcohol present in the wash, the balance (3-4 per cent.) remaining as highly concentrated impure alcohol.

(5) By the introduction of devices, losses of alcohol and entraining liquid are almost completely cut out and without additional expense, and

(6) Because all existing distilling plants can easily be altered to permit of their use for dehydrating alcohol; as well as all plants arranged for producing anhydrous alcohol direct from wash may, if and when required, be used for the production of absolute alcohol from raw spirit of any concentration or for the production of ordinary rectified spirit.

Manufacturing cost of absolute alcohol by azeotropic processes—It will be clear from the preceding description that the manufacturing cost of absolute alcohol would in no case exceed the cost of production of 95 per cent. alcohol plus the cost of dehydration of the same. It has already been stated that the recent achievements in improving the process, enabling the production of anhydrous alcohol directly from the wash in one operation, make it possible to produce absolute alcohol at almost no extra expense than that necessary for ordinary rectified spirit (95-96 per cent.)

In the calculations that follow I have assumed therefore that 95 per cent. alcohol is being dehydrated the cost of production of which was worked out at annas 6 per gallon assuming that the price paid for molasses was annas 6 per maund delivered at the distillery. It has further been assumed that the plant is capable of dealing with 8,000 gallons of rectified spirit producing 7,600 gallons of absolute alcohol per day, and that it will work for 350 days in the year.

The three main items of expenditure in the azeotropic process are steam, water and the loss of the entraining liquid every day. The consumption of steam and water will in no case exceed 10 lb. and 30 gallons respectively for every gallon of absolute alcohol produced, while the daily consumption of the entraining liquid requires some consideration. Since the azeotropic process for making dehydrated alcohol has not been commercially tried in India, it seems slightly problematic to make an estimate of the daily loss of this liquid under Indian conditions. It may be pointed out that the improved methods of Usine de Melle, E. Merck, and the Acme Copper Smithing and Manufacturing Co. have succeeded by using scrubbers in reducing the loss of the entraining liquid to as low as ·06 gallons per 100 gallons absolute alcohol produced under foreign climatic conditions. I was told by a big American concern that a daily loss of 20 gallons of the entraining liquid will take place in a plant producing 7,600 gallons of absolute alcohol under Indian conditions. I am consequently taking this figure for my calculations. It may again be pointed out that the following calculation should be considered the utmost cost of producing absolute alcohol these days under Indian conditions.

Calculated cost of anhydrous alcohol

Capacity—Producing 7,600 gallons of absolute alcohol per day from 8,000 gallons of rectified spirit (95 per cent.) on the basis of working 350 days in the year.

	Per day. Rs.	a.
Materials and utilities		
Rectified spirit 8,000 gallons at 6 annas per gallon ..	3,000	0
Steam at 10 lb. per gallon of absolute alcohol, 76,000 lb. requiring 9 tons of coal of 7,000 B.T.U. at Rs. 15 per ton	135	0
Water at 30 gallons per gallon of absolute alcohol at 2 annas per 1,000 gallons	28	8
Total ..	3,163	8

Cost per gallon = $\frac{\text{Rs.}3,163\text{-}8}{7,600}$, say about 80 pies per gallon.

Labour

[illegible] per month 4 0

Cost per gallon = $\frac{\text{Rs.}4}{7,600}$, say 0·1 pie per gallon.

Indirect Expenses—A quotation of 45,000 dollars has been given to me by Messrs. The Lummus Company of New York for a plant

of the above capacity. This will approximately correspond to Rs.1,25,000 at the present rate.

	Per day. Rs. a.
Depreciation at 10 per cent. on Rs.1,25,000	35 10
Interest and Insurance at 10 per cent. on same	35 10
Maintenance	15 0
Total ..	86 4

Cost per gallon = $\frac{\text{Rs.86·4.}}{7,600}$, say about 2·2 pies per gallon.

Summary of the cost of production of absolute alcohol in India

(*Cost per gallon of absolute alcohol*)

Materials and utilities	80 pies per gallon.
Labour	0·1 ditto.
Indirect expenses	2·2 ditto.
Total cost per gallon of absolute alcohol ..	82·3 pies or 6 as. 10 p.

To this must be added the Licence Fee of about ½ anna per gallon, so that the cost of manufacturing absolute alcohol will in no case exceed 7 annas 6 pies per gallon under Indian working conditions.

I am inclined to believe that if any of the modern methods for manufacturing absolute alcohol directly from the wash is adopted in India the production cost of absolute alcohol will be lowered by about 1 anna than the figure of 7 annas and 6 pies per gallon that I have calculated.

There are three important processes which come under the heading of azeotropic processes :

(1) Melle Process of Messrs. Usine de Melle, Paris, which uses a mixture of Benzine and petrol (about half and half) as the entraining liquid. This firm charges a royalty of about ½ anna per gallon on the quantity of absolute alcohol produced.

(2) The Drawinol Process of Messrs. E. Merck Chemical Works, Darmstadt, Germany, which uses Trichlore-thylene as the entraining liquid. This firm also charges a royalty of about ½ anna per gallon on the quantity of absolute alcohol produced.

(3) The process of Messrs. The ACME Copper Smithing and Manufacturing Co., of Oreland, Pa. (U. S. A.), which uses only Benzene as the entraining liquid. This firm charges no royalty for their process.

The only troublesome point about the adoption of the azeotropic processes in India is that the entraining liquids will have to be imported from outside, unless arrangements for their manufacture are made in India. Besides this, the absolute alcohol produced by the azeotropic distillation always contains traces of the entraining liquid, thus rendering it unfit for the manufacture of very fine chemicals, which require absolute alcohol free from traces of the ordinary entraining liquids.

This, however, is immaterial if the alcohol is to be used for power purposes.

2. *Salt dehydration processes*

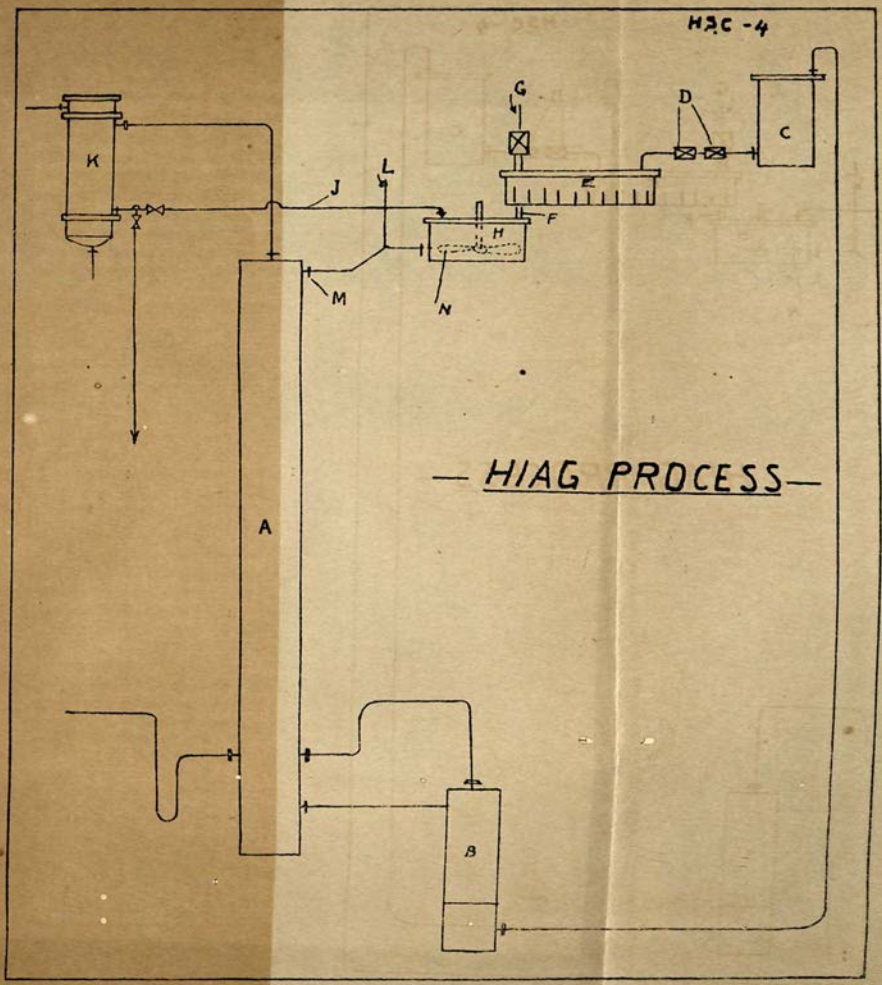
(*a*) *Hiag process*—The Hiag process utilizes as the dehydrating agent a mixture of salts composed of 70 per cent. potassium acetate and 30 per cent. sodium acetate, the melting point of the mixture being about 240°C. In the process this salt mixture never appears in the solid form. It is present either dissolved in alcohol, water, or as molten mass. The salt is in these fluid forms throughout the cycle and in the normal operation is never solid. The general working of the Hiag apparatus will be clear from the drawing below—

The rectified spirit is entered into the tall dehydrating column A near its bottom and is heated by means of closed steam coils. The vapours of rectified spirit rise up in the column. This column is filled up with Raschig rings so as to increase the surface of contact between the alcoholic vapours and the solution of the dehydrating salts trickling down from the top. The dehydrating agent together with water and some alcohol is drawn off from the bottom of column A. It is then deprived of its alcohol in the small column B, the thick salt layer remaining is then pumped into the elevated container C. The water-laden dehydrating agent in the container C then passes through the regulating valve D into the heating pan E, where it is dehydrated and the fusion of the salts effected. The heating pan E is provided with a closed coil which is heated by superheated steam at 300°C., so as to keep the dehydrated salts in a fused condition (240°C.). The feeding of the salt solution from the column C to the heating pan E is fixed at such a rate that by the time the salt reaches the outlet from E, it goes completely dehydrated and is in the fused condition. The molten mass flows continuously through the pipe F into the mixing vessel H. The mixing vessel H is continuously supplied through pipe J with some of the anhydrous alcohol from the condenser K, where it is formed by the condensation of the anhydrous alcohol vapours coming out from the column. The solution of the dehydrating salts in absolute alcohol flows from the vessel H into the column A near the top.

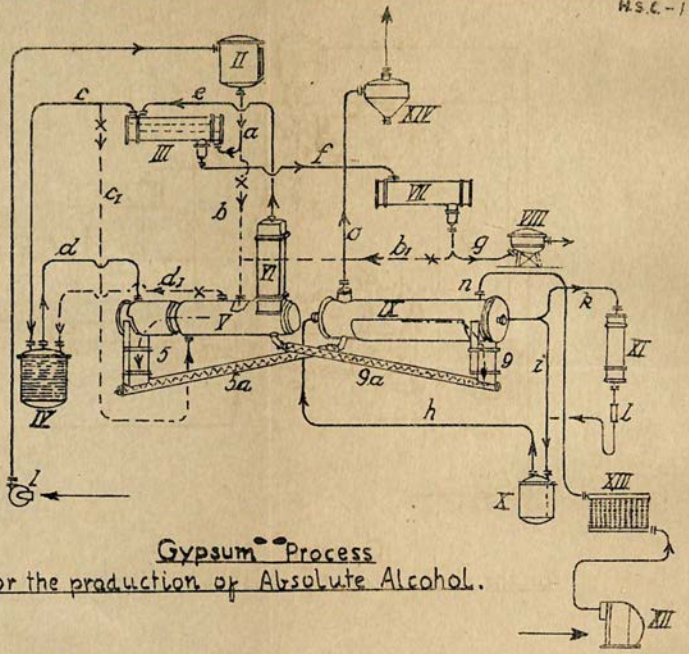
The absolute alcohol obtained by the Hiag process is of a very high purity and comes out at 99·8° G. L. It can be satisfactorily used in the manufacture of fine chemicals requiring very pure alcohol. The dehydrating salts (potassium and sodium acetates) are very cheap and there is hardly any loss of the salts during the process. The plant works almost automatically.

(*b*) *Gypsum process*—The dehydrating agent used in this process is water-free Gypsum ($CaSO_4$). The salt is used in finely powdered form in a drum, which is inclined at an angle of 50° and whose length

HAC -4



— HIAG PROCESS —



Gypsum Process

For the production of Absolute Alcohol.

depends on the capacity of the plant. This drum is connected to a drive so that the gypsum powder is slowly moved from the upper to the lower end. The alcohol vapours pass through the drum counter-currently, thereby being dehydrated. The gypsum takes up such a quantity of water that the half-hydrate results ($CaSO_4\frac{1}{2}H_2O$). This half-hydrate is also in the form of a powder and parts with its water of crystallization at 175°—185°C. The dehydration of the half-hydrate is accomplished by letting it pass slowly through another similarly inclined revolving drum externally heated to the required temperature. A further absorption of water by the gypsum with simultaneous formation of higher hydrates and lumps does not take place even in the presence of an excess of alcohol vapours.

In order to avoid partial dead-burning in the regeneration process, the semi-hydrate is freed from its water by indirect heating with the vapours of liquids of suitable boiling point and is returned into the alcohol dehydrating process. The heat developed as well by the heating of the gypsum as by the formation of the hydrate is utilized for the vapourization of part of the alcohol. The description given below of the drawing that follows will illustrate the working of the process more clearly.

The raw spirit is raised by a pump I from a storage tank into the elevated overflow or measuring tank II. The outlet pipe (*a*) conducts it through a series of measuring devices to the pre-heater III, where it is preheated by the vapours of absolute alcohol arriving from filter VI. It then passes through (*c*) into the evaporator IV, from where it enters in the vapourized state through (*d*) into the dehydrating cylinder V, where its water content is bound by the anhydrous calcium sulphate moving in counter-current.

In order to take advantage of the considerable amount of heat developed by the absorption of water, cold spirit is sprayed through the pipe (*b*) into the cylinder V directly on to the calcium sulphate.

The alcohol vapours being now dehydrated to at least 99·8 per cent. leave the cylinder V through the automatic dust filter VI, pass through the preheater III by (*e*) and (*f*) into the cooling tank VII, where they are liquefied. The absolute alcohol passes through the safety filter VIII and through means for testing its density, and is withdrawn from the plant to storage tanks.

The gypsum used for dehydrating and now converted to a semi-hydrate is then regenerated in continuous circulation and is used over again. It leaves the alcohol dehydrating cylinder V through 5 in the direction indicated by the arrow, enters into the dehydrating cylinder IX by means of the worm 5a, from where it returns in the anhydrous state through 9 and 9a into the alcohol dehydrating cylinder.

The vapours of an organic heating liquid boiling in X are conducted through (*h*) to heat the gypsum-cylinder IX. The liquid resulting from

the condensation of the said vapours flows back into the tank X through (i), while any uncondensed vapours will circulate through (*k*) to the cooling tank XI, from where the condensed liquid is returned to X by (l).

The ventilator XII blows fresh air through the heater XIII to enter into the cylinder IX at (*n*), and the air charged with steam passes through (*c*) to the cyclone separator XIV and thence into the open air.

In case it is desired to dehydrate the vapours of spirit coming directly from a rectification column without intermediate condensation, the parts I, II, and III of the apparatus shown may be omitted.

The special advantages of the Gypsum process are :

1. That the dehydrating cylinder contains no liquid alcohol.
2. Raw spirit can be dehydrated without any special preliminary purification and without higher steam consumption. Methyl alcohol, if present, does not need be separated but is dehydrated simultaneously.
3. In actual practice absolute alcohol is exclusively obtained, there being no fractions of lower grade.
4. The dehydrating agent is cheap and obtainable in most countries.

(*c*) *Alumina process*—The Alumina process has recently been developed by the Alumina Corporation of America and has not yet been tried on a commercial scale. The process utilizes aluminium oxide (alumina). The alumina is freed from water upon heating to 175°C., and can then, similar to gypsum process, abstract the water from alcohol vapours.

Comparison of the salt dehydrating processes—In contrast to the Hiag process, in the gypsum process we deal with a solid substance, necessitating the use of complicated mechanical equipment. Secondly the gypsum, being in a finely powdered form, is partly carried away by the alcohol vapours so that the filtration of the dehydrated alcohol has to be done in a special apparatus. Another disadvantage of the gypsum process lies in the fact that, depending upon the quality of the alcohol used, the gypsum takes up more or less impurities and thereby becomes un-utilizable. Even with the purest spirits a gypsum loss of 44 lb. per day has been recorded in a plant producing 2,700 gallons of absolute alcohol per day. The manipulation in the replacement of spent gypsum measurably complicates the process.

For the production of 26½ gallons of absolute alcohol via the Hiag process there are required 143 lb. of steam, 1 cubic meter of water and 0·2 to 0·4 K.W.H. of electric power.

For the gypsum process the steam and cooling water requirements are practically the same as for the Hiag process. The electric power requirements are once again as great because of the moving of the reaction drums and the solids more power is needed than for the Hiag process which requires only a stirrer.

The principal advantage of the Hiag process over the Gypsum process is that no solids are handled. The clogging up of parts of the apparatus

is thus impossible. The contamination and the corresponding loss of salts, when using aldehyde and fusel oil free spirits, never occurs. Against this the gypsum process of the I. G. is very sensitive so that even when using pure spirits a definite daily loss occurs, and with a small amount of impurities this loss rises sharply.

The loss of alcohol in the Hiag process is 0·3 to 0·4 per cent. a higher loss than this has never been observed. Against this the recorded loss of alcohol in the gypsum process is stated to be 0·5 to 1 per cent. This comparatively great loss in alcohol is traceable to the fact that in the gypsum process the last traces of water are removed from the gypsum through the use of hot air. Naturally, along with this water there is some alcohol which has been absorbed by the gypsum. The alcohol which is thus withdrawn from the gypsum is lost as the air is led outdoors. In the gypsum process 220 lb. of water-free gypsum is required for the dehydration of 26 gallons of alcohol, while in the Hiag process only 44 lb. of the salt mixture are required per 26 gallons.

The point mentioned above clearly indicates the superiority of the Hiag process over the gypsum process of the I. G.

In contrast to the Gypsum process the Alumina process uses the Aluminium oxide in the form of fixed bodies, which are very hard and not easily worn away in practical usage. We can guess from this that the Alumina Corporation is of opinion that the use of finely powdered dehydrating material greatly complicates the process. The advantage of the Alumina process over that of Gypsum is in the utilization of larger sized particles. This material is kept in closed reaction towers, thus avoiding moving parts. This, however, is a disadvantage in that the alumina becomes unreactive like the gypsum, besides the replacement of the material in the absorption towers is naturally a drawback and will necessitate occasional shut downs. The dirtying of the dehydrating material in the Alumina process will indeed occur much more rapidly than in the Gypsum process, while the effective outer surface of the dehydrating agent becomes distinctly smaller. As to the rest the Alumina process works like the Gypsum process. The Alumina process, however, can only be judged properly after a number of plants have used it for some time.

It may be clearly stated that the cost of manufacturing absolute alcohol by any of the Salt Dehydration Methods is in no case lower than the cost of production by the Azeotropic method making absolute alcohol directly from the wash. At the same time local and other economic conditions have helped a great deal in maintaining the production of absolute alcohol by the Salt Dehydration processes to the present time. From the information that the writer has been able to collect about the working of these processes, he is inclined to think that the cost of production of absolute alcohol by either of the Salt Dehydration processes will not exceed Re.0-1-6 per gallon over that of 95 per cent. rectified spirit.

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In a tropical country like India, where the Azeotropic process have not been tried so far, where the loss of the entraining liquids cannot be definitely stated, and above all where the entraining liquids will have to be imported, it is worthwhile to give a trial to either of the salt dehydration processes, specially the Hiag process and see how it fits in our local climatic and economic conditions. The writer has specially been inclined to make this recommendation for the Hiag process on account of the fact that the dehydrating mixture of sodium and potassium acetates can easily be manufactured in India from Acetic acid, the manufacture of which from waste molasses in India has been dealt in a previous chapter, and even assuming that it cannot be so manufactured, it would not be necessary to import them from time to time, as there is hardly any loss of the dehydrating salts in the circle of operations.

The writer understands that experimental work has recently been carried out at the Sugar Research Laboratory at Cawnpore by Dr. H. D. Sen and his associates pertaining to improvements in the Hiag process, both in regard to rectifying columns as well as in the dehydrating mixture, for which patents are pending. The dehydrating mixture to be used consists of potassium acetate and caustic potash. It is intended to prepare the potassium acetate by installing a small vinegar plant attached to the distillery so as to make the process independent. Research work of this nature is highly important to be carried out on a semi-large scale before any definite statement can be made as to which, of the so many existing processes for making absolute alcohol, is most suitable under Indian conditions.

CHAPTER VI

The conditions in India

Present position of India with regard to the development of alcohol as a carburant

It may be stated at the very outset that no alcohol is being used in India at the present time as a Carburant. All the requirements for the Carburant are met by the petroleum industry of Burmah. The consumption of gasoline in India is estimated to be about 72 million gallons per year. Assuming that we decide to use an alcohol-gasoline blend of 25 per cent. alcoholic content, there would be required for this motor-fuel at least 18 million gallons of anhydrous alcohol, which could be easily produced from 9 million maunds or 330,000 tons of molasses.

The yearly production of molasses in India is estimated to be about 500,000 tons, so that the supply of the raw material from year to year is expected to remain in excess of the demand for power alcohol purposes. The supply of the molasses for the industry being thus assured, and in the absence of other outlets for the utilization of molasses in India, it is clear that the prices of the raw material for the power-alcohol industry are bound to remain stable, and generally to the advantage of the distillery.

India, unlike most other countries, has the unique advantage that the cost of production of power alcohol will be much lower than the present prices at which gasoline is sold in this country, so that it is possible to market the alcohol-gasoline blend at a cheaper rate than straight gasoline. Assuming the selling price of annas 10 per gallon of absolute alcohol and Rs.1-10-6 per gallon for petrol and using a 25/75 blend, it is clear that the price of the blended motor-fuel will be reduced by about 4 annas per gallon to the benefit of the motoring public.

The present capacity of the distilleries in India is insignificant to supply the entire demand of alcohol for motor-fuel purposes that would be required annually. Even the few existing plants will have to be overhauled and reinstalled for the production of anhydrous alcohol.

Furthermore, overhauling the existing plants and the building of new ones would contribute materially to increased employment. These operations would increase the demand for equipment machinery, building construction, freight tonnage, skilled and unskilled labour, and finally even coal for operating these plants.

The prompt development of the manufacturing capacity sufficient for providing alcohol for blending to the extent of 25 per cent. in motor-fuel would require some extraordinary measures, either to induce private capital to undertake the building of plants or to furnish capital through some Government agency. One of the main problems to be met is that

of insuring the future of the industry. Doubtless private capital could be obtained for the construction and working of the plants, if continuous operation on a profitable basis could be insured for a number of years and especially if it were reasonably certain that the demand would increase and that there would be opportunity for the industry to expand.

Under present conditions some special measures would have to be undertaken to secure or insure the use of any considerable quantity of alcohol in motor-fuel. It would be hazardous for private capital to enter upon extensive construction programme without substantial assurance that some Government policy of maintaining the industry would be carried through. An important factor in the cost of manufacturing is the cost of the plant. The continuous operation of the plant through a period of years tends to reduce the costs. Private capital cannot enter into the business and sell alcohol on a low cost basis without assurance of a high rate of operation through a period of years.

Furthermore, the manufacture and use of industrial alcohol to stabilize the market for molasses by using larger quantities when supplies are abundant and cheap and curtailing operations when sugarcane crops are short and prices high, may be properly considered a public enterprise to be operated by or under close supervision of the Government. Such a policy could be followed to protect the consumer against being compelled to pay excessive costs of manufacturing or excessive profits on account of the hazards of the industry, as well as to provide an outlet for surplus molasses and help to establish and maintain a more satisfactory position of sugarcane agriculture in the national economy of India.

In considering the development of the power alcohol industry as a public enterprise to be operated by or under close supervision of the Government, we cannot overlook the fact that the petroleum industry of Burmah is also an indigenous industry of India and has endeavoured to supply all the requirements of the nation in this respect almost exclusively from its own resources up to the present time. From the point of view of the oil industry, the question of alcohol fuel is undoubtedly an exceedingly controversial one, which is easily understood, since every gallon of alcohol blended with motor fuel replaces an equivalent quantity of petroleum motor spirit. It is specially so in these days of over-production when it is only natural that any movement tending to decrease the consumption of petroleum products should be regarded with the utmost disfavour and suspicion by those who have put in their best talent, energy and capital in bringing up the indigenous petroleum industry to its present stage of development.

Such being the state of affairs at the present time in India, Government should naturally not be inclined to enforce the use of alcohol-gasoline blend by legislation. Such a decision will only create bitter

dissatisfaction and antagonism between the petroleum and the sugar groups so that the chances of success of such a measure will only be far remote. The best plan for the success of the alcohol industry would be to secure the co-operation of the two rival groups in such a way, feasibly under Government patronage, that their best interests are maintained in the development of the new industry.

Ideal conditions in India for the development of alcohol as a carburant on its own merits

Many of the foreign countries have made it compulsory for the Oil companies to purchase a certain percentage of home made alcohol in relation to their distributed gallonage of motor spirit with a view to assisting the farming industry. Forcing alcohol on to Oil companies by the aid of the law could only result in antagonizing the companies who disposed of the alcohol by indiscriminately mixing it with inferior grades of heavy commercial petrol producing a motor-fuel, which was altogether unsatisfactory for use in private cars, and inevitably the motorists in the countries where this policy was carried out became equally antagonized against alcohol blends. The main point which weighed with the Governments of most of these countries in enforcing the use of the alcoholic blends through legislative measures was that petrol was in almost every case an imported product and obtainable at much lower rates than the production cost of alcohol from farm products which were intended to be used in order to afford protection to agriculture. Natal, on the other hand, has developed the power-alcohol industry through the help of a preferential tax—by reducing the tax on petrol intended to be used for blending—while no legislative measures of any kind have been deemed necessary in the case of Philippine Islands. The use of alcohol as a Carburant has developed in the islands on its own merits and on account of its being cheaper than gasoline. Contrary to receiving any encouragement from the Government the alcohol industry of the Philippine Islands pays heavy revenues to the Government by way of excise taxation.

However, the fact that the Cities Service Oil Company, Ltd., England, is today distributing an alcohol mixture may, therefore, appear to call for some explanation, particularly for so far no legislation has been enacted in Great Britain nor is at present likely to be enacted necessitating the compulsory use of home-produced alcohol in motor-fuel. In this connexion reference may be made to the gradual decline in the sale of No. 1 grade petrol and the consequent increase in the use of commercial spirit by the average private motorist during the last few years, who no longer sees any particular advantage for paying a couple of pennies more per gallon for No. 1 grade petrol, unless the petrol has some particular advantage which makes its superior performance obvious to motorists in comparison to the usual commercial spirit.

The big oil concerns have frequently carried out surveys with the object of determining as to which particular property in petrol is most appreciated by the motorists, and usually in the past some point, such as easy starting, freedom from carbon deposit, acceleration, or mileage per gallon was given the first place. Anti-knock value was generally placed well down on the list. Such surveys have been quite misleading, for whether motorists themselves are aware or not of the fact, there is little doubt that, excluding price per gallon, anti-knock value is in actual practice the principal property on which depends the demand for motor-fuel today. It is certainly true that if a petrol gave extremely difficult starting from cold, excessive carbon deposit, or extraordinary poor mileage per gallon, it would not meet with success even if its anti-knock value were particularly high. The present position, however, is that all reputable motor spirits give reasonably good starting, and no appreciable difference can be detected in their tendencies to carbon up the cylinders or the number of miles which can be covered in one gallon. This similarity does not hold good, however, in the case of anti-knock values, and therefore the only characteristic in respect of which a motorist can discriminate is to note the extent to which his engine can be made to "pink" or knock on a particular fuel. It can thus be maintained that the quality of a motor spirit at the present time is entirely governed by its anti-knock value, i.e., its octane rating.

It has been explained in a previous chapter that alcohol is one of the best agents employed at the present time for increasing the anti-knock value of the motor-fuels. The use of 20 per cent. benzol or the addition of small percentages of tetra-ethyl lead for the same purpose is less efficient, besides having certain limitations.

The bulk of the motor spirit produced at the present time in Burma and used almost exclusively in India may be said to have an anti-knock value varying between 60 to 65 octane, which could be easily increased from 80 to 85 octane if the oil companies co-operate to supply the Indian motoring public with a better grade of motor-fuel than the one that is being distributed at the present time. In addition to this advantage they would also be in a position to market the improved fuel at a lower price than that at which straight gasoline in being sold these days. When the petroleum companies in other parts of the world are utilizing alcohol for improving the anti-knock value of their gasoline at increased cost of manufacturing the blended fuel, it does not stand to reason why the Petroleum Concerns of Burma should be so reluctant as not to utilize the alcohol for blending with gasoline, specially when it can be done at an actually reduced cost of the blend.

Frankly speaking the Power Alcohol issue has become so confused that it is now difficult to apportion the objections raised between the alcohol mixtures themselves, the opposition to such compulsory legislation, and the natural reluctance of vested interests to welcome a new competitor.

In some countries the major oil companies sell such blends voluntarily. Even in the United States the power alcohol question has become a major issue between rival industries, each fighting for self-protection or greater expansion, rather than a matter of relative fuel quality alone. Interest in this subject is spreading in Great Britain and many concerns have been watching with close interest the efforts of an independent concern, Cities Service Oil Co., Ltd., to build up a market with an alcohol blend. This has been done so far successfully on a small but expanding scale and the experiment has been carried out undisturbed by the shadows of compulsory legislation. It is very possible that we shall shortly hear of further developments in England on the same lines.

It may be hoped, therefore, that better counsels will prevail with those directly connected with the petroleum industry of Burma and that it will be possible to secure the co-operation of both the groups in finding out the ways and means by which the future of the power alcohol industry could be insured for a number of years to come. If this were successfully done in the near future there is no doubt that the motorist in India would be using a much better fuel at a much less expense before long.

It would be apparent from what has been said above that the present time represents ideal conditions in India for the development of alcohol carburant on its own merits. Such ideal conditions have never been possible to be obtained in any other country, where the power alcohol industry is already well established today.

Discussion on the necessity of legislation

In most foreign countries special legislative measures have been undertaken as a means of inducing the use of alcohol in motor fuel. In some cases the measures have taken the form of compelling the distributors of motor fuel to buy alcohol proportionate to the amount of gasoline used or sold by them, it being allowed to make whatever mixtures they find expedient. In some cases attempts have been made to compel the use of a specified percentage of alcohol in the fuel. In other cases the use has been induced or encouraged only by preferential taxation. As previously indicated in only a few countries such as Sweden, Philippine Islands, and England, has the use of alcohol been induced upon its own merits technical and economic. Doubtless some quantities of an alcohol-gasoline blend could be sold in India at the same price or even slightly lower than straight gasoline only on account of superior smoothness of operation and anti-knock quality. Extensive use, however, could be induced only by legal requirements in some form of a differential tax or other special inducements.

The mixing of a given percentage of alcohol with gasoline could probably be induced in India in either of the three ways :

(1) By legally requiring a mixture of a specified percentage.

(2) By reducing the existing petrol tax on petrol intended for blending, or

(3) By requiring the petrol distributing agencies to purchase a certain percentage of alcohol in relation to their distributed gallonage of petrol.

The first of these possibilities, viz., compulsory mixing of gasoline and alcohol would involve important questions of administration and of constitutionality. It appears advisable to limit consideration to the problem of including the utilization of the alcohol for fuel by any of the remaining two methods.

Reducing tax on blended fuel—If the Government of India could see its way in reducing the present petrol tax of annas 10 per gallon to only annas 8 per gallon on petrol intended for blending and continue to levy the present petrol tax on petrol to be used straight for motor fuel, there would be some inducement in favour of the utilization of blends. This, however, would dry up a part of the Central revenues, which, assuming that all the petrol used was blended, would not amount to more than 20 per cent. of the present revenue from this source. There is no doubt that the adoption of this measure would deprive the State of large amounts of revenue, the gasoline tax being one of the most stable and productive sources of revenue. Other sources are yielding far less revenues today than a few years ago and new sources are hard to find. Taxpayers everywhere register determined resistance to new taxes. Consequently, any reduction in the State revenues from petrol tax, as a measure of inducing the utilization of the blended motor-fuel, is hardly to be expected because of the difficulty resting primarily upon the serious revenue problem involved. The present revenue derived from petrol is about 4·5 crores of rupees. There is no doubt, however, that this loss of revenue could be redeemed to a very great extent by putting some excise tax on the power-alcohol produced and by the increased sales of the petrol, which are bound to result when the motor fuel were made available at lower rates.

The adoption of such a method in India should not cause any apprehensions of fall of Central revenues from petrol tax, and a few years' trial alone will show how it has actually helped in the developement of the power-alcohol industry to the ultimate relief of the farmer.

Forcing alcohol on the petrol group—The third measure, i.e., requiring the petrol distributing agencies to purchase a certain percentage of alcohol in relation to their distributed gallonage of petrol, has also worked satisfactorily in most of the foreign countries and deserves consideration. The success of such a measure depends to a great extent on the co-operation and goodwill of the petroleum people. A modest beginning could be made by persuading the petroleum group to purchase 1, 2, 3, or 4 per cent. of alcohol according to their distributed gallonage of petrol and make the best use of it. This plan would have several advantages :

1. It would simplify administration. It would be necessary only to determine whether wholesale distributors or other concerns operat-

ing on a large scale, handling substantially all the fuel for a given area, used the agreed percentage of alcohol according to their distributed gallonage of petrol during a fixed period.

2. It would enable dealers to blend alcohol and gasoline in such proportions as to give the best performance of motor fuel in the light of technological considerations and public preference.

3. It would enable dealers to use the alcohol more extensively with low grade gasoline, and thus add an economic value through greater improvement in the performance of the mixture than might be obtained from using the alcohol with high-grade gasoline.

4. It would be possible and more economical to sell a relatively larger quantity of alcohol in those provinces where its use seemed most acceptable and desirable.

The use of a flexible blend under Indian conditions appear to have distinct advantages for administrative, technical and economic reasons.

Effect of substitution of alcohol on the oil industry

The substitution of alcohol for gasoline would obviously have economic repercussions on the oil industry. If all the motor fuel in future were to be blended fuel, and if the amount of the blend that would be sold to motorists annually should be the same as the amount of gasoline being sold at the present time, then obviously the petroleum refining industry would sell less gasoline. The reduction in sales of gasoline would be equal to the total sales of the blend multiplied by the percentage of alcohol included.

The amount of blend sold, however, might be more or less than the amount of gasoline sold in the recent past. Extension of surfaced highways is no doubt bound to proceed in the near future in view of the activities of the Roads Development Committee in India. Attractive opportunities for motoring will thus increase. The improvement of the economic condition of the public on account of the development of the power-alcohol industry and the assistance thus given to the sugar industry is likely to increase the amount of money available for motoring expenditure. The reduction in the price of the blended fuel will also have a liberal effect on the consumption of motor fuel, so that it is quite possible that the oil refining industry will find itself selling considerably more gasoline than indicated above.

Moreover, a decrease in the total gasoline sales would not necessarily be accompanied by a corresponding decrease in the scale of refinery operations. Gasoline is only one, although the most important one, of a number of the products of refineries. There is considerable room for variation in the proportions in which they are obtained from a given grade and volume of crude oil.

For some of these products the market in India has been increasing and promises to continue to increase. This is particularly true of fuel oil, the most important item. The import of fuel oil in India during the

pre-War year (1913-14) was only 7,766,000 gallons and has risen up to 104,837,000 gallons during 1933-34. Indications are that this expansion will be continued. Fuel oil, in addition to being used in locomotives, is coming into use in Diesel electric rail cars in many of the foreign countries. Substitution of such cars for ordinary train service is a promising way of reducing the expenses of branch line operation and of providing service in smaller units at more frequent intervals. The substitution of fuel oil for coal under steam boilers in steamships and the construction of Dieselengined ships using fuel oil has been an outstanding feature of world navigation developments during recent years. On the whole, however, the possibility of diverting crude petroleum from gasoline to fuel-oil seems very strong.

The two next important products of the industry are lubricating oils and illuminating oils (the latter chiefly kerosene). The market for lubricating oils will increase gradually with the development of the power-alcohol industry and transportation. Petroleum has no important competitor as a source of lubricants. Of the minor products, asphalt and asphaltic oils have special interest. Extension of improved highways in the future must largely improve the demands for these products.

The point of the foregoing discussion is not that the oil industry by exercising greater pressure in the sale of petroleum products, other than gasoline, could make up for its future loss of gasoline sales by developing a greater use of fuel-oil, etc. than would otherwise occur. It is only that the normal growth of motor fuel consumption will offset all or part of the loss of substitution of gasoline, and that the balance of crude petroleum, if any, for which a gasoline outlet is lost may be absorbed by the expected future growth of fuel oil sales, etc. The industry may not attain as high a general level of production in the future as might otherwise occur, but it can still attain a level equal to or materially above that of the present time.

Necessary distillery capacity for the disposal of molasses in India

The estimated production of molasses in India is considered to be about 500,000 tons per year. Assuming that all the quantity of molasses were to be utilized by conversion into alcohol, there would be required some 10 units of the capacity of 7,600 gallons of absolute alcohol per day. Reckoning on the basis of 55 gallons absolute alcohol yield from a ton of molasses there would be produced in India same 27,500,000 gallons of absolute alcohol per year to be disposed of. The annual consumption of petrol in India is about 72 million gallons. Assuming that all the carburant to be used in future were to be an alcoholic-petrol blend of 25—75 composition it would be possible to utilize at the most about 18 million gallons of absolute alcohol, which represents about 65 per cent. of the estimated total production of alcohol from the molasses in India every year. If alcohol to the extent of 25 per cent. of the annual consumption of motor-fuel were required or desired for use within a year

or so, this could be only possible by postponing the effective date of the requirement until stock could be accumulated. Some time would be required to overhaul the existing plants and adapt them for the production of absolute alcohol. Time would also be required for the distribution of alcohol throughout the country to make it available for use in blending with gasoline. In the meantime stocks of molasses will continue to accumulate and make the molasses problem still more acute.

It will be evident from what has been said above that the utilization of molasses for the production of alcohol carburant alone cannot solve the molasses problem of India. It will certainly go a long way in helping out the sugar industry and if adopted as a long time measure will prove beneficial to Government, the petroleum group, the sugar group, the distiller, the distributor, and the planter of sugarcane.

Due importance should, however, be given to other outlets for the consumption of absolute alcohol, which could be possibly developed in India under the existing conditions. For instance the consumption of alcohol for heating and illuminating purposes could easily be increased to a considerable amount in India under proper publicity and encouragement.

On the whole there does not appear to be any doubt about the success of the power-alcohol industry in India if undertaken with leadership and enterprise at the present time.

Possibility of disposing of absolute alcohol for burning purposes in admixture with kerosene oil

It has been shown in a previous chapter how ideal conditions exist in India for the development of the alcohol carburant on its own merits without any Government legislation. For giving encouragement to the development of the power alcohol industry, one of the suggestions made was to impose a preferential tax on the quantity of pertol to be used for blending, i.e., to continue to levy the present petrol tax of annas 10 per gallon on petrol to be used straight and to reduce it to annas 8 per gallon for the quantity of petrol to be used for blending. There is no doubt that such measure will reduce the Government revenues to a certain extent but this can be more than compensated by levying a very nominal tax on kerosene oils, the consumption of which in India for illuminating purposes is quite enormous, being 58,147,000 gallons in 1933-34.

Experimental work in other countries has shown that absolute alcohol could be used to advantage in admixture with kerosene for illuminating and heating purposes giving better heating and illuminating efficiencies. Patents of Messrs. Srivastava and Sen are pending on different absolute alcohol mixtures with kerosene oils of various grades under the name of "Daylight Oils". These compositions have the property of remaining homogeneous even at very low temperatures and having flash points sufficiently high to ensure their being used with comparative safety in ordinary Hurricane lanterns and stoves with less deposition of soot and

greater brilliancy. It has been found possible to replace about 1/3rd of kerosene with denatured absolute alcohol, producing thereby a mixture which can easily fetch a better price on its own merits. The imposition of a small tax on kerosene would not be felt by the consuming public because of the better qualities of the mixtures available for their use.

In view of the estimated low cost of production of alcohol and the market prices for the various grades of kerosene oils at the present time in India, this use of alcohol seems very promising to be adopted in conjunction with the development of the Alcohol Carburant in India. The loss of revenue accruing to Government by reducing the petrol tax on petrol used for blending can be easily compensated by levying a small tax of 6 pies per gallon on kerosene oils consumed in India.

Recommendations for the development of the power alcohol industry in India

Under the existing conditions in India no useful purpose can be served by legally requiring the use of alcohol-petrol blend of a specified composition. The difficulties involved will be those of administration, constitutionality, as well as of economic considerations in respect of distribution and blending. The writer has been given to understand that the petrol group in India is very hostile to the idea of using alcohol as a carburant and consequently no co-operation from them is to be expected in this regard. It would be a wrong policy under the circumstances to force the petrol distributing agencies to purchase a certain percentage of alcohol in relation to their distributed gallonage of petrol.

1. The best plan under the circumstances appears to be to allow a preferential tax of annas 2 per gallon on petrol used for blending, i.e., the Government should continue to levy the present tax of annas 10 per gallon on petrol but should give a rebate of annas 2 per gallon on petrol used for blending.

2. In order to compensate the loss of Government revenues by the introduction of preferential tax on petrol used for blending a tax of 6 pies per gallon should be charged on kerosene. The imposition of this nominal tax will not be felt by the taxpayer and will afford an inducement for mixing alcohol with kerosene for illuminating and burning purposes. This will provide a further outlet for the disposal of absolute alcohol.

3. There should be no (or only nominal) excise duty on power alcohol intended to be used for carburation, illumination, or heating purposes.

4. It is very essential that the present denaturants be replaced with petrol, crotonaldehyde, or fusel oil and other special denaturants for specific industries in which alcohol has to be used.

5. A beginning should be made by allowing the installation of at least one 8,000 gallons capacity unit in the United Provinces for the production of absolute alcohol.

6. Every possible facility should be provided for the encouragement of alcohol consuming industries.

Some people hold the view that the development of the power-alcohol industry could be easily induced in India if the Government were only to fix the minimum price at which petrol could be sold in the different localities. It has been suggested that an excise duty of annas 10 per gallon could be charged on power-alcohol in order to compensate the loss of government revenues, which might result from the decreased consumption of petrol due to partial replacement with alcohol. Such a measure is hardly to meet with success if we consider its scope of operation throughout India on account of the fact that the major portion of petrol is consumed in India in the neighbourhood of the port towns while most of the power-alcohol industry would be located in the United Provinces and Bihar. Consequently the cost of production, excise duty, transportation, and handling charges on alcohol would be prohibitive for its economic use in those territories where the major portion of petrol is being consumed at the present time.

There is no doubt, however, that a little inducement could be given to the power-alcohol industry if the scope of operation of this measure were restricted to certain selected territories, e.g., United Provinces. The present selling price of petrol in the United Provinces is about Re.1-10-6 per gallon so that the minimum selling price could well be fixed at Re.1-8 per gallon. Assuming that specially denatured absolute alcohol could be sold for, say, annas 10 per gallon plus an excise tax of annas 10 per gallon, and assuming also that the selling price of the blend would also be the same as that of petrol, i.e., Re.1-8 per gallon, then the distributor of the blend will get the following profit :

	Rs.
Price of 100 gallons blend of 20/80 composition	150
Cost of 80 gallons of petrol at Re.1-8 per gallon	120
Cost of 20 gallons of alcohol at Re.1-4 per gallon	25
Total ..	145

This leaves a margin of Rs.5 per 100 gallons for the distributor of alcohol/petrol blend. It is to be seen if any distributor considers this return as sufficiently remunerative to take it up and arrange the distribution of the blend himself and do the necessary advertising to make its use popular among the motorists of his territory.

To the best of the writer's knowledge the distributors of straight petrol get a commission of about 12½ rupees per 100 gallons at present.

Unique position of the United Provinces with regard to the development of the power-alcohol industry

The United Provinces occupy a very acute position with regard to the question of the utilization of molasses. The annual production of molasses in this province is over two-thirds (about 300,000 tons) of the total

production of molasses in the whole of India. It is geographically situated so far away from the port towns that the transport charges for purposes of export would be prohibitive in relation to the prices obtainable in the foreign markets for molasses. The annual consumption of gasoline in this province amounts to only about 5 million gallons so that we can at the most use about 1 million gallons of absolute alcohol for carburation purposes in admixture with petrol as a blend of 20/80 composition. The quantity of molasses that could thus be utilized for power-alcohol purposes would not exceed 18,182 tons annually. The development of the power-alcohol industry in this province will therefore only provide an outlet for about 6 per cent. of the total quantity of molasses produced from year to year. The availability of the raw material in such excessive quantities coupled with the high ruling prices of petrol in this territory should be a very attractive proposition for the development of the power-alcohol industry in this province. That such a development has not come about so far is probably due to the fact that the Government do not want to go to the extent of passing any legislation enforcing the use of alcoholic-blends (knowing full well that such a measure would only provide an insignificant outlet for the huge quantity of molasses produced every year in this province), while private capital is shy to enter into this business unless its future is assured against competition with the petroleum group. The petrol group itself do not seem to have any favourable interest in this matter at the present moment, but will nevertheless do so when they will find alcohol being forced on them through legislative measures. The following important points should be kept in mind in the development of the power-alcohol industry in these provinces :

(i) The distilleries should be situated in close proximity of the sugar factories and should preferably be attached to them. They should be in areas where petrol consumption is high and where the price of petrol is high.

(ii) Suitable denaturants for use in power alcohol should be prescribed, e.g., 0·2 per cent. crotonaldehyde and 3 per cent. petrol or benzole.

(iii) If the petroleum interests disagree to take some share in the development of this industry, it will become necessary for Government to take the help of legislature for encouraging the use of alcohol for carburation purposes.

(iv) There should be no excessive duty on home made alcohol.

If the above conditions are fulfilled, there is no doubt that a big power alcohol industry could be established in the United Provinces on very sound lines.

It has been mentioned before that the use of alcohol in admixture with petrol affords only a very insignificant outlet for the huge quantity of molasses produced every year in these provinces. A decidedly better

scheme to be adopted in the United Provices would be to develop the use of a fuel which can take up considerably larger quantities of alcohol than is possible in admixture with petrol from economic and technical considerations. The British Improved Motor Spirit (Holdings) Ltd., London, have quite recently taken out patents for just such a fuel. Until this fuel was invented, no fuel had been known which allowed use of a higher percentage of alcohol than 20 per cent. without proportionately increasing the consumption of the fuel; that is to say, without decreasing the mileage per gallon. This Motor Spirit consists of 70 per cent. alcohol (rectified), the balance being a small portion of benzole and large portion being a hydrocarbon now obtained by a narrow cut fraction from petroleum spirit. This fuel has been reported by authorities on the subject to have the following advantages:

(*a*) Consumption approximately equals that of petrol.

(*b*) Smoother and cooler running of the engine. Greater power and therefore better acceleration.

(*c*) Practical elimination of carbon deposit. Easier starting from cold.

(*d*) No obnoxious fumes from the exhaust. Considerable reduction in the consumption of lubricating oil.

(*e*) It is anti-knock (knocking or pinking is impossible).

(*f*) Less evaporation than with petrol. Far higher compression can be used.

(*g*) No separation of the constituents nor does it freeze even at —90° centigrade.

(*h*) It can be manufactured by a simple process.

This fuel has been fully tested by the Italian Ministry of Agriculture, the Dunlop Rubber Company, and by Professor A. W. Nash, who has the Chair of Petroleum Technology at Birmingham University and is a recognized authority on this subject.

By the use of this fuel—

1. The sugar producers of the United Provinces would have a much bigger market for the alcohol produced. They would not have to incur the expense of dehydrating plants.

2. The petrol distributors would not have to disturb any of their existing arrangements, or alter their blends, and would make a greater profit per gallon at least in these provinces, where petrol has to bear high transport charges from the port and consequently sells at high prices. As the fuel contains 70 per cent. alcohol, there would be a saving of 70 per cent. in freight charges and 70 per cent. in evaporation and other losses. The petrol companies would continue to supply all requirements of petrol up to an economic distance from the ports of delivery as at present.

3. Under this scheme the Government could continue to receive its revenue as from petrol.

It is suggested that either a Central Company should be formed to operate this fuel under licence in India, or else separate companies in such districts where alcohol can be most cheaply produced starting from those places where the petrol prices are highest.

The sugar factories should take a financial interest in this company, providing the molasses either free or at a nominal cost, and taking its profits from the dividends of the company.

The petrol distributors might also be financially interested in this concern, undertaking all distribution and marketing without disturbing any of their existing arrangements.

The British Improved Motor Spirit (Hoddings) Ltd. could also receive shares in the Company and a royalty on turnover.

The Government might also be represented in the Company.

Before any decision, however, is arrived at by the Government in regard to the future of the Power Alcohol Industry it is essential that a small conference be called consisting of the petrol group, the sugar group, and some members of the Government to discuss the issue and arrive at some tentative proposals to secure the co-operation of all the parties, without which the future of the Power Alcohol Industry can scarcely be considered secure.

Conclusion

The problem of molasses appears to have become so important recently in India that public men, journalists, University professors, and others have felt it necessary to express their opinions in the press as well as on the public platform. It seems necessary therefore to consider in greater detail the real extent of the molasses problem in India. The total production of molasses in India is estimated to be about 427,000 tons per year. Out of this quantity the production from cane sugar factories is 237,000 tons; from *gur* refineries about 40,000 tons, and from *khandsari* system about 150,000 tons per year. The share of the United Provinces alone in the above quantities is 123,000 tons from cane sugar factories, 27,000 tons from *gur* refineries, and practically the whole of *khandsari* molasses are produced in these provinces. It is obvious therefore that if there is a molasses problem anywhere in India it must be the most acute in the United Provinces, which produce no less than 70 per cent. of the total output of the country.

The first point for consideration is to see how much of the above quantity of molasses is an actual surplus in India which may be available for purposes of export or for directing into new channels of utilization. Actual figures for the normal consumption of molasses in India are not readily available at the present time. A vague idea could, however, be

formed by taking the average production of molasses in India during the five years preceding the War plus the average imports of molasses for the same period. This comes to 80,000 tons and 93,000 tons respectively. Due to the absence of a good market for *khandsari* molasses for the last two or three years, the *desi* sugar manufacturers have now started to reboil their molasses and sell it as cheap *gur*. It has been estimated that about 50 per cent. of the *khandsari* molasses are now being so treated. Deducting these approximate figures for the normal consumption of molasses from the total production, we are left only with an actual surplus of about 175,000 tons of molasses, which have to be disposed of.

A molasses exporting company has recently been formed in India, for the purpose of exporting molasses to other foreign countries. The price which this exporting company can pay for molasses will naturally depend on the transport costs and the prices ruling in the various foreign markets for molasses. While this company may be able to effect some contracts with the sugar factories situated near the port towns, it is not expected to have much business with those located very much farther in the interior. Molasses, though regarded by many as a waste product at present, represents so much potential wealth to the nation. Its disposal at a low price means a loss of that wealth. Its proper utilization in the country itself can save this great national loss.

Utilization of molasses—It does not seem worthwhile to repeat the long list of possible uses to which molasses could be put as are obviously unlikely to succeed in India at the present time, e.g. manufacture of dry ice, yeast and the various chemicals. The following are mentioned as some of the possible uses which might deserve consideration under Indian conditions :

(*A*) *Uses in the Sugar Industry*—

(i) Fuel,

(ii) Recovery of sugar, and

(iii) Conversion into edible molasses.

Molasses have occasionally been used as fuel to supplement that afforded by bagasse; but it is considered that such use would be uneconomic and troublesome in the long run.

The recovery of sugar from cane sugar molasses by selective fermentation is still under laboratory trials in some of the foreign sugar-producing countries; while the work of the late Dr. E. R. Watson and his associates (by a modification of the well-known Battelle's process) has not so far been tried on a commercial scale. It is not possible therefore to recommend its adoption at the present stage.

That cane molasses are a remarkably wholesome food is quite generally known and almost universally conceded to be true. The consumption of edible molasses is quite popular in the United States of America and is estimated to be about 8 million gallons per year. Edible molasses

are made by a suitable admixture of the first and second molasses and then subjecting to cold storage before packing under different brands. In two of the plants large quantities of such edible molasses are solidified in a powder form and sold as "MOLASKA" for the confectionery and ice-cream industry. It should be possible to develop a big market in India of edible molasses for the confectionery and canning industries. The manufacture of edible molasses will materially help the Indian sugar industry by reducing the quantity of the third molasses, which have at present got to be produced under the existing practice of the sugar factories.

(*B*) *Industrial uses*—

(i) Road surfacing,
(ii) Acetic acid manufacture, and
(iii) Production of alcohol.

Reference has already been made of the valuable work in the field of road surfacing by molasses done in the sugar section of the Harcourt Butler Technological Institute, the Agricultural College, and by the Government of Mysore. It is, however, very doubtful if any of the methods adopted for road surfacing can pay a price of more than annas 2 per maund for molasses in comparison to other road surfacing materials on the market.

The manufacture of acetic acid and specially glacial acetic acid has some future in India. The present imports of acetic acid and allied products amount in value to about 10 lakhs of rupees per year, which could be easily retained in the country. Future expansion of the Indian film and rubber industries is likely to provide additional markets for acetic acid produced here.

It is well known that molasses is the cheapest and the best raw material for the alcohol industry. It is interesting to note that 84 per cent. of the total alcohol produced in the world is made directly from molasses. It may be pointed out that with a serious molasses problem existing in India at the present time we are still importing about a million gallons of methylated spirits (95 per cent.) valued at about Rs.10 lakhs per year, representing an output from about 15,000 tons of molasses. The difficulty in the way of Indian distilleries to secure this market lies in the fact that large quantities of methylated spirits are consumed near the ports whilst the distilleries are situated mostly in the interior and cannot bear the high transport charges on alcohol so as to compete with imported spirits near the port towns. Unless the import duty on methylated spirits is raised from 7½ to 25 per cent. there does not appear much chance of further expansion of this industry.

A number of standardized processes are in operation in the various foreign countries for producing absolute alcohol or power alcohol (99·7 per cent.) at almost the same price as methylated or rectified spirit. It

has been proved beyond doubt that it is possible to produce power alcohol in India at about 6 annas 6 pies per gallon, taking the price of molasses at 5 annas per maund delivered at the distillery. This absolute alcohol could be used for illuminating and heating purposes or for carburation purposes in the internal combustion engines of our motor cars.

Investigations in the laboratories of the Sugar Section of the Harcourt Butler Technological Institute, Cawnpore, show that 33 parts of absolute alcohol could be mixed with advantage with 66 parts of low grade kerosene to produce a high grade mixture for illuminating and heating purposes. The annual consumption of kerosene in India is about 60 million gallons, which could take up about 20 million gallons of alcohol, representing an output from about 3€4,000 tons of molasses per year. Such a use can only be developed in this country if alcohol industry is given general encouragement by the State, specially in the form of lighter excise duties than prevail at present.

The other use to which absolute alcohol could be put is to mix it with petrol to form a fuel for motor cars in a blend of 20/80 composition The present consumption of petrol in India is estimated at about 80 million gallons per year, the major part of which is consumed near the port towns. This can take up about 16 million gallons of power alcohol. The efficiency of such a mixture has been unanimously accepted in most of the foreign countries, so much so that about 40 different nations of the world are at the present time using it in place of straight petrol in their motor cars, either by compulsory legislation, preferential tax, or on its own merits as a carburant. Such a use cannot be brought about in India without Government legislation enforcing compulsory blending, while the Government of India do not feel justified in favour of passing any such legislation. It involves complicated questions of administration, constitutionality as well as difficulties in respect of economic transportation and distribution. The adoption of an alcohol/petrol blend on an all-India basis is thus out of the question. It has been suggested in the press by some exponents of power alcohol that since the problem of molasses disposal is felt most acutely in the United Provinces, provincial legislation to secure the desired end would be advisable. It must be borne in mind, however, that the annual consumption of petrol in these provinces is estimated to be about 5 million gallons, which can take up only one million gallons of power alcohol for admixture with petrol in a blend of 20/80 composition. Even supposing that the Government of the United Provinces do pass such legislation, it will only provide an outlet for about 18,000 tons of molasses, which is a very insignificant figure considering the annual production of about 300,000 tons of molasses in these provinces. Other advocates of power alcohol have expressed the view that the development of the power alcohol industry in the United Provinces does not depend on the charity of the Government to pass any special legislation favouring its use. The writer cannot

agree with such exponents of power alcohol. The cost of production of power alcohol will amount to not less than 6 annas 6 pies per gallon, and one will have to pay 10 annas per gallon as duty, 2 annas 6 pies as transport charges, and allowance must be made for a minimum profit of 2 annas per gallon. It would thus not be possible to sell such power alcohol for less than Re.1-5 per gallon. It has then to be mixed with petrol in the ratio of 20 : 80 and sold as the New Fuel on a parallel distribution organization and in competition with petrol. Such a commercial undertaking hardly appears worthwhile to attract the attention of any industrialist.

Assuming that the U. P. Government decide to give encouragement to the power alcohol industry against unfair competition by the petrol group through an abnormal cut in the prices of petrol, it will be necessary to fix a minimum price at which petrol is to be sold in the markets of the United Provinces. Even if the present price of Re.1-10 per gallon is fixed as the minimum price of petrol, the distributor of the New Fuel will hardly have any margin of profit to induce him to sell this mixture in competition with petrol and put up a parallel distribution organization. It must be clearly understood that the only chance for the development of the power alcohol industry in these provinces lies in either getting a preferential treatment from the Government or in the co-operation of the petrol and the sugar group to develop this industry for their mutual benefit.

A fuel has recently been patented in England, India and other countries by Messrs. The British Improved Motor Spirit (Hoddings) Ltd., which takes up 70 per cent. of methylated spirit (95 per cent.), about 3 per cent. of benzol, and the balance of a petrol extract obtained by a narrow cut fraction from petroleum spirit. This fuel has been tested by very competent authorities on the subject, who unanimously report that it is at least as good as the best grades of petrol in addition to being anti-knock. The chances for the development of such a fuel are much greater in these provinces than those of an alcohol/petrol mixture, which is being so much advocated at the present time. Such a fuel should receive all possible encouragement in the United Provinces instead of a 20 per cent. alcoholic blend because of the much larger quantities of molasses that will be consumed.

(C) *Agricultural uses*—

(i) As a potassic fertilizer,
(ii) As a direct manure, and
(iii) As cattle feed.

Patents have recently been taken in India for the manufacture of a potassic fertilizer from molasses after incinerating them in a special furnace. The product so obtained is potassium carbonate in a very crude form containing about 32 per cent. of potash and 1·5 per cent. of phosphoric acid. A fertilizer of the above composition will have to sell

at about Rs.3 per maund in competition with other potassic fertilizers obtainable in the market. To prepare and sell at this price with a reasonable profit the molasses would have to be available at about 1 anna 6 pies per maund. This can hardly be considered a profitable method for the utilization of molasses.

Dr. N. R. Dhar of the Allahabad University has recently carried out valuable researches in the field of molasses utilization as a direct manure. Field experiments on his lines have been carried on by the Department of Agriculture, United Provinces, from which it appears that it is only likely to prove economic if used within five miles from the source of supply and when selling ex-source at not more than 2 annas per maund. The value of molasses as direct manure, in fact, depends on the rapidity with which nitrate formation takes place in the soil. This is only possible when the ratio between the carbon and nitrogen is as 10 :1. Thus for every unit of carbon released from its combination in organic matter undergoing decomposition in the soil, a definite amount of nitrogen is necessary to be present in the soil. It is therefore suggested that instead of applying molasses directly to the soil, it should be first converted into manure by sprinkling diluted molasses solution on the activated compost heaps and the activated compost should be used as direct manure. The adoption of such a method would be much more economic and practical, as it would not be necessary to give innumerable ploughings and irrigation two or three months before sowing as suggested by Dr. Dhar. The conversion of molasses into manure, however, should be taken up as the last resort when other avenues for the utilization of molasses have been exhausted as the return in this way is bound to be very small. The findings of Dr. Dhar that nitrogen fixation takes place in the complete absence of bacteria are corroborated by other foreign authorities in this line who hold the view that while nitrification and possibly nitrogen fixation can be brought about in the absence of bacterial life, only a small percentage of the action taking place under natural conditions can be attributed to non-living causes.

Cattle-feeds from molasses—The history of molasses as a feed for livestock dates back to the beginning of the nineteenth century. The popularity of molasses for cattle-feed purposes in foreign countries gradually increased from year to year, and it is estimated that now over one-third of the total molasses produced in Europe are used as forage for stock. In recent years the molasses-feed industry has grown up rapidly in the United States of America. The 1906 report of analyses of commercial feeds made by the Louisiana Experiment Station contains analyses of 8 molasses feeds manufactured by three companies; and the same report for 1917-18 contains analyses of 149 molasses feeds put on the market by 41 manufacturers. A similar rise in the use of molasses feeds has taken place in other states as well. The following is the average composition of the 149 samples of molasses feeds analysed at the Louisiana

Experimental Station : Water—11·7 per cent., Protein—10·6 per cent., Carbohydrates other than fibre—52·3 per cent., Fibre—15·5 per cent., Fat—2·9 per cent., and Ash—7·0 per cent. These figures show that the molasses feeds, as then offered, were very similar in composition to Oats or Bran. Generally speaking, the molasses feeds, made up with roughages with and without concentrated grain, vary in general average percentage composition as follows : Water—9 to 17, Protein—8 to 14, Carbohydrates other than fibre—45 to 54, Crude fibre—6 to 20, Fat or other extract—1 to 6, and Ash—6 to 10 per cent. The ordinary grains do not absorb molasses very well; that is why fibrous feeds are often incorporated in the mixture. They permit the inclusion of a much larger quantity of molasses, approximately up to a half of the total weight.

From chemical composition molasses must be considered as a strictly carbohydrate food. Their palatability, specially of those produced from cane, adds to their feeding qualities and reputation. It is stated that when fed in moderate amounts cane molasses are about equal, pound for pound, to dent corn for fattening steers, horses, dairy cows, sheep and pigs; while in the beet sugar districts the beet molasses are valued at about three-fourths as much per ton as corn. By thinning it and pouring it over or mixing it with roughage, animals may be induced to eat more roughage and waste less than otherwise. This is specially important when feeding unpalatable low grade roughage as is the common practice in India.

Amount of molasses to be fed—Opinions differ somewhat as to the amount of molasses that can be safely fed to farm animals. Rations mentioned by Stackhardt, Kenneberg, and Stohman consisted of molasses, oatstraw, and hay. They limited the proportion of molasses to 8 lb. per 1,000 lb. of the live weight of the animal fed. Kelner who is in practical agreement with Maercker, Morgen, and other German investigators advocated approximately the following amounts of beet molasses daily per 1,000 lb. live weight: Horses 2—3 lb., Steers 2—3 lb., Sheep 4—8 lb. and Swine 4—5 lb. The Director of Agriculture, United Provinces, had some experiments carried out in his department on the feeding of molasses to farm animals. His report goes to show that molasses can be effectively used as a stock-feed. The common complaint that *sheera* tends to be too heating when fed to animals arises from the fact that when fed it is apt to be given with ordinary fodder as the sole source of concentrates. The result is that the diet is badly balanced being unduly rich in carbohydrates and deficient in proteins. It is necessary to balance the diet of the molasses-fed animals by suitable inclusion of such proteid materials as oilcakes, *chuni* and cotton-seed meal to obtain the best results.

In conclusion the writer would like to emphasize that of all the methods of utilization of molasses dealt with so far, the only one which seems most practicable, economically sound and having unlimited scope for future expansion in India is the manufacture of cattle-feeds from

molasses. India being mainly an agricultural country, it is logical that the bullock should receive greater consideration than the automobile, that the manufacture of cattle-feeds should be much more encouraged than that of power alcohol, acetic acid, fertilizers and road-surfacing materials. This solution of the molasses problem can be easily and quickly achieved without any necessity of Government legislation or fear of competition from outside. It is gratifying to note that the Imperial Council of Agricultural Research has realized the great scope of this method of utilizing molasses and has recently made a grant to carry out experimental work in this connexion in the Sugar Section of the Harcourt Butler Technological Institute, Cawnpore, under its Sugar Technologist.

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